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ABSTRACT

This report presents a detailed accounting of a study to measure maintenance productivity and to explore how commanders can enhance this productivity at the Strategic Air Command 19th Bomber Wing at Robins A.F.B., Georgia. Utility models for the Deputy Commander for Maintenance and the Squadron Commanders of the Field Maintenance Squadron, Organizational Maintenance Squadron, Avionics Maintenance Squadron have been completed. Those factors which contribute most to maintenance effectiveness have been identified and the relative importance of each established.

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I. INTRODUCTION

A problem which faces most organizations is the requirement for some type of effectiveness measurement. Effectiveness is defined as the relationship between organizational outputs and inputs. This problem is usually complicated and can become particularly difficult in a non-profit environment when effectiveness has many objective and subjective characteristics. If organizational outputs are measured in several areas, the problem of aggregating the measures of each area into one overall measure of effectiveness arises. Studies of the ability of humans to perform complex information processing indicate a limited capacity in terms of the number of measurable characteristics.[1-3] These measurable characteristics are frequently called attributes.

This concept of limited human information processing is readily accepted by most decision makers and leads to a decomposition of a situation with many measurable characteristics into individual attributes for which it is believed organizational effectiveness can be judged quite well. This decomposition act has the concurrent requirement that a methodology must be assumed or developed which will combine the results of measuring individual attributes into an overall measure of effectiveness. Many reported applications utilize the assumption of a simple linear addition for combining individual attribute values into an overall single measurement. The validity of the

assumptions made to justify use of this simple linear additive utility model is often questionable, or worse, these assumptions are ignored.

More generalized approaches are available which yield an overall utility model for a decision maker which more accurately reflects the actual environment in which he operates. These more complex approaches will be presented in Chapter II.

Multi-attribute utility theory is commonly applied to those decision-making problems where the possible decision consequences, or alternatives, are characterized by more than one attribute. For example, a manufacturer contemplating the purchase of a new production machine might evalute candidates using four attributes: initial cost, operating cost, production capacity, and compliance with safety and environmental regulations.

In this study multi-attributes utility theory was applied in a new way to develop an overall measure of effectiveness to provide commanders with a mechanism to measure the effect on effectiveness of various decisions they make. It will also indicate the maximum effectiveness that the commander can expect to achieve given the constraints under which he operates.

A key element of utility theory, and a possible shortcoming, is that the decision maker, with the assistance of analysts, completely specifies his own utility function. He does this by identifying

attributes, specifying attribute utility functions, weighing attributes, and by responding to various analysts' questions regarding attribute independence conditions which leads to the form of the overall utility function. Productive interview techniques were employed by the analysts to ensure that decision makers' responses were accurate and consistent.

The criticism of utility theory centers around its lack of transferability. Since a utility function explicitly reflects the preference structure of a single decision maker, it is valid only for him but with limited success may be transferred to a different decision maker in a highly structured organization.

This study is concerned with the measurement of effectiveness

II. LITERATURE REVIEW

This chapter is divided into two sections; the first section provides a review of the development of utility theory and the second section deals with previous research concerning the measure of effectiveness in the United States Air Force.

Development of Utility Theory

Although the concept of maximizing expected monetary return dates to the eighteenth century, modern utility theory for decision making was first developed in 1947 by von Neumann and Morgenstern [4] who postulated a set of axioms using objective probabilities. They demonstrated that a utility value could be assigned to each possible decision outcome in such a way that the decision maker should always choose the outcome with the highest expected utility. This result is referred to as the expected utility hypothesis.

Savage [5] provided the next major contribution in 1954 when he presented the first axioms concerning subjective expected utility, which incorporates subjective probability estimates made by the decision maker. In the following years a collection of results for problems involving uncertainties became known as Bayesian or statistical decision theory as presented by Schlaifer [6], Raiffa and Schlaifer [7], and Pratt, et al [8]. The application of statistical decision theory to actual problems led to the coinage in 1966 of the term decision analysis.[9]

Researchers have investigated more specific characteristics of decision problems since the mid-1960s. Pratt [10], Schlaifer [11], and Novick and Lindley [12] have explored various methods to assess utility functions. The assignment of subjective probabilities was examined by Winkler [13], Edwards [14], Schlaifer [11], and Tversky and Kahneman [15]. Arrow [16] and Keeney and Kirkwood [17] developed results for group decision problems, and Fishburn [18-20], Pollak [21], Raiffa [22], Keeney [23, 24], and Keeney and Raiffa [25] investigated multi-attribute preferences.

The utility functions to be developed for Armament Systems and Computer Sciences at Eglin AFB are multi-attributed in a partially risky environment. The environment is partially risky because some attributes can be measured with certainty while for other attributes, only the probabilty distribution or expected value of an attribute measurement can be obtained. However, this report assumes certainty for all attributes.

A simple additive utility model for n attributes is of the form:

$$u(x) = \sum_{i=1}^{n} k_i u_i(x_i) \qquad (2.1)$$

where

$u(x)$ = expected total utility value

k_i = weighting of attribute i, $i = 1, 2, \ldots, n$

x_i = a specific amount of attribute i

$u_i(x_i)$ = expected utility of x_i

Since the term utility function will be used only when at least one attribute cannot be measured with certainty, u(x) will hereafter be referred to as the utility of x with the understanding that u(x) is actually the expected utility of x.

Fishburn [26] proved that the additive utility model for two attributes, say X and Y, is applicable if and only if X and Y are additive independent. Attributes X and Y are additive independent if the paired preference comparison of any two lotteries, defined by two joint probability distributions on X by Y, depends only on their marginal probability distributions.

Fishburn [26] extended this result to the general n-attribute case. The utility function takes the form of equation (2.1) if and only if the set of attributed (X_1, X_2, ..., X_n) is additive independent. That is, if preferences over lotteries on X_1, X_2, ..., X_n depend only on their marginal probability distributions.

In order to get a better feel for additive independence, consider e conditions under which it can be assumed that two attributes are independent.

Let (A;B) denote a lottery yielding consequences A and B with an equal probability of 0.50. This is commonly referred to as a "fifty-fifty" lottery. Let x and x' be specific values of attribute X, and y and y' be specific values of attribute Y.

Attributes X and Y are additive independent if the decision maker is indifferent (i.e., prefers neither over the other) between two lotteries L_1 and L_2, where the two lotteries are defined as follows:

$$L_1 = ((x,y);(\underset{\cdot}{x}',\underset{\cdot}{y}')) \qquad\qquad L_2 = ((x,\underset{\cdot}{y}');(\underset{\cdot}{x}',y))$$

The multilinear utility function was also developed by Fishburn [19] with further refinements by Farquhar [27] and takes the form:

$$u(x) = \sum_{i=1}^{n} k_i u_i(x_i) + \sum_{i=1} \sum_{j>i} k_{ij} u_i(x_i) u_j(x_j)$$

$$+ \sum_{i=1}^{n} \sum_{j>i} \sum_{m>j} k_{ijm} u_i(x_i) u_j(x_j) u_m(x_m) + \ldots + \qquad (2.2)$$

where the notation is identical to that for equation (2.1) except for the additional weighting constants ($\underset{\cdot}{k}$'s) with multiple subscripts. The determination of these added weighting constants is given in Keeney and Raiffa [25].

The multi-linear utility function is applicable only when each attribute in the attribute set is utility independent of the remaining attributes. Let X_i denote one attribute in the attribute set and let $\overline{X}_i$ denote the complement of X_i (all other attributes). X_i is utility independent of its complement if the conditional preference order for lotteries involving only changes in the level of attribute X_i does not depend on the levels at which the attributes in $\overline{X}_i$ are held fixed.

Keeney [28] presented the multiplicative utility function in 1974. If attributes X_1, X_2, ..., X_n are mutually utility independent, then the utility function takes the form:

$$ku(x) + 1 = \sum_{i=1}^{n} (kk_i u_i(x_i) + 1 \qquad (2.3)$$

where k = constant to scale u(x) from zero to one.

Attributes X_1, X_2, ..., X_n are mutually utility independent if every subset of $X = (X_1, X_2, ..., X_n)$ is utility independent of its complement. Note that the assumption that is required for the multiplicative utility function is more restrictive than the assumption for the multilinear model. In fact, the multiplicative model is merely a special case of the multilinear model.

The multiplicative utility function has been successfully applied in a number of environments. Keeney and Raiffa [25] presented several example applications.

It is now clear that the form of the utility function applicable in a given decision-making circumstance depends on the various independence conditions that exist among the attributes.

Measurement of Air Force Maintenance Effectiveness

No reported application of utility theory to the measurement of effectiveness has been found, either in the public or private domain.

Hays, et al [29] employed utility theory to evaluate a U. S. Navy warfare system. They essentially made a straight-forward application of Keeney's multiplicative model and developed no new theory.

Research concerning U. S. Air Force manpower effectiveness abounds, particularly at the Air Force Human Resources Laboratory at Wright-Patterson AFB, Dayton, Ohio [30]. These studies are more narrow in scope than this study since they deal only with manpower effectiveness. Obviously, the measurement of effectiveness must account for non-personnel as well as personnel attributes.

A sampling of research into manpower effectiveness is provided by references [1], [31], [32], and [33].

The Air Force Systems Command did experiment with value or worth models during the 1960s. Rand Corporation [34] evaluated these models in 1976. Honeywell created a procedure called PATTERN. Another program called TORQUE was also developed later to make decisions on missile development. These models were additive, hence variables were assumed to be completely independent with no interaction. These and other objections forced the program into disuse.

III. PROBLEM STATEMENT AND EXPERIMENTAL DESIGN

The purpose of this study was to develop utility functions which will provide a measure of effectiveness. These utility functions can then be used to aid commanders in their attempts to enhance productivity.

A description of the process of utility function development follows. The first step is to determine which factors (attributes) the appropriate commander considers to be relevant in the measurement of effectiveness. The attribute identification step is not concerned with relative attribute importance but solely with the enumeration of all possible attributes. This identification is no trivial step as an attribute overlooked can significantly change the form of the overall utility function. Attributes which are considered to be insignificant by decision makers should not be discarded at this stage. Any such attributes will emerge during attribute weighting and can be eliminated at that time. A decision maker may be reluctant to divulge his complete attribute set or may even be unaware of subconscience attributes which can only be exposed with the help of analysts.

The second step in utility function development is to determine a quantitative measurement scale for each attribute, including identification of the lowest and highest possible attribute values.

Several attributes will have a natural measurement scale such as average experience, manning level, work time, space, and budget. Other attributes will require an arbitrary measurement scale (such as 0 to 5 or 0 to 10).

The third step is to develop the utility function for each attribute over the entire range of possible attribute values. Each utility function is scaled such that a utility of 0 corresponds to the least desirable attribute value and 1 corresponds to the attribute's most desirable value. The utility function expresses the utility (or value) to the decision maker for each possible attribute value.

Analysts can employ one of several methods available to determine a person's utility function. The simplest but most inconsistent technique is to request the decision maker to sketch the shape of his utility function. An improved method is to ask the decision maker to estimate his utility for various attribute values along the measurement scale and from these estimates, rough in the utility function. The most consistent method found for developing utility functions is the lottery technique described by Raiffa [28] and this method was used in this study.

The fourth step in utility function development is the investigation of attribute independence conditions. The form of the overall utility function depends on the existence of certain independence

conditions among the attributes. Two types of independence must be investigated - preferential independence and utility independence.

For a n-attribute set let X_i and X_j denote any two attributes and let $\overline{X}_{ij}$ denote the complement of the attribute pair X_i and X_j, that is, all other attributes. X_i and X_j are preferentially independent [25] of $\overline{X}_{ij}$ if the conditional preferences by the decision maker in the (X_i, X_j) space given $\overline{X}_{ij}$ do not depend on the particular values of the attributes in $\overline{X}_{ij}$.

Let $\overline{X}_i$ denote the complement of attribute X_i or all attributes in the attribute set except X_i. X_i is utility independent [25] of $\overline{X}_i$ if the conditional preferences for lotteries on X_i give $\overline{X}_i$ do not depend on the particular values of the attributes in $\overline{X}_i$.

One or more of several methods shown in Figure 1, was used to handle attribute dependencies. The first approach consists of combining dependent (preferentially or utility dependent or both) attributes into one attribute which encompasses the original dependent attributes and which possesses the desired independence properties. The difficulty with this approach is that it may be much harder for the decision maker to perform the necessary tradeoff analyses which are required for development of the attribute utility function and attribute weighting.

Another approach to dealing with attribute dependencies is to maintain the original attribute set and acknowledge the dependencies

by assessing conditional utility functions for the affected attributes. This method poses added assessment problems just as the first one does. Decision makers may find it very difficult to articulate conditional utility functions.

A pragmatic approach which has been successfully employed [25], is to assume that the desired independence conditions exist even if experimentation fails to confirm them. This assumption may be valid when a sensitivity analysis shows that the affected attributes have little impact on the overall utility function. It cannot be justified otherwise.

The fifth step in utility function development is to determine the weighting, or relative importance, or each attribute in the overall utility function. Each attribute scaling constant is some number greater than zero and less than one. As it was for the development of attribute utility functions, a lottery technique provides the most consistent results for attribute weighting [25].

For a n-attribute set, let the vector $\overline{x}^{\circ}$ denote the consequence of each attribute at its least desirable level and $\overline{x}^{*}$ denote the consequence of each attribute at its most desirable level. Similarly let x_i° and x_i^{*} denote the least desirable and most desirable level of the specific attribute X_i, respectively. Let k_i be the weighting for attribute X_i and let $(x^{*}; x^{\circ}, p_i)$ denote a lottery yielding consequence x^{*} with probability p_i and yielding consequence $\overline{x}^{\circ}$ with probability $1-p_i$. Since $u(\overline{x}^{*}) = 1$ and

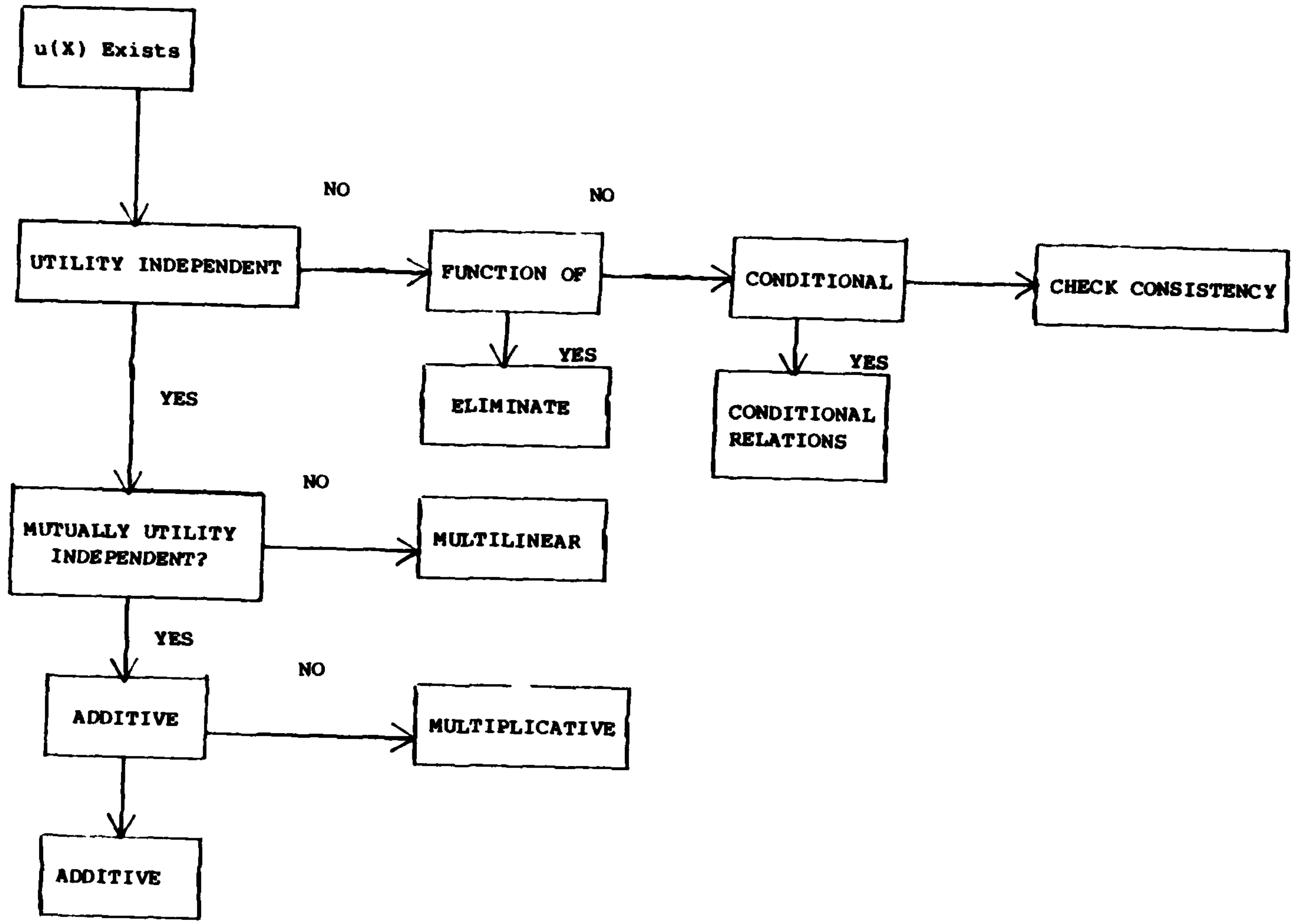


FIGURE 1. ASSUMPTION TEST ORDER

$u(x^{\circ}) = 0$, the expected utility of the lottery is $p_i(1) + (1 - p_i)(0) = p_i$. The decision maker is asked to choose a value of p_i such that he is indifferent between receiving $(x_1^{\circ}, x_2^{\circ}, \ldots, x_{i-1}^{\circ}\ x_i^{*}, x_{i+1}^{\circ}, \ldots, x_n^{\circ})$ for certain or the lottery $(x^{*};x^{\circ}, p_i)$. The utility of the certainty equivalent is $k_i u_i(x_i^{*}) = k_i(1) = k_i$. Since the utility of (x^{*}, x°), is p_i, then $k_i = p_i$. Thus when the p_i values are selected for each attribute, the decision maker is actually weighting each attribute.

The sixth step in utility function development is to assess the various attribute measurement uncertainties. The probability distribution of attribute ratings must be determined for all attributes which cannot be measured with certainty. For example, a commander may subjectively rate morale on an arbitrary zero to ten scale. When a morale rating is made, say a value of six, the following questions must be answered.

1. Can the commander state with certainty that the current morale is at the six level on the attribute measurement scale?

2. If the morale rating cannot be made with certainty, is the true morale equallty likely to be higher or lower than the estimated value? If so, the probability distribution of the true attribute rating may be symmetric about the estimated value.

3. What is the maximum error possible in an estimated attribute value?

The answers to these and related questions will lead the analysts to the form of the attribute measurement probability distributions. These probability distributions will then be used to calculate the (expected) utility for a specific attribute measurement if that attribute cannot be measured with certainty.

If the attributes are not utility or preferential independent and sensitivity forces us to examine the relationship of conditionally related variables, Bell's procedure [35] may be used to approximate to any degree of accuracy desired. The computation required is to assess 2m marginal utility functions $\mu(X_i/Y_i^{\circ})$ and $\mu(X_i/Y_i)$ together with $2^m - 2$ corner constants. For example, for m=5, too many utility values would result for most analyst-decision makers to access. Fortunately in most cases m will rarely be as great as four even when twenty or more variables are identified.

The final step is to determine the overall utility function.[25]

The second goal of the study was to determine how the various commanders can improve effectiveness as measured by their respective utility functions. This process consisted of two stages. The first step was to determine the set of decisions that are made or could be

made by each commander. The second step was to determine quantitatively the impact of each commander's possible decisions on his overall utility value. The final product of this process was a set of decision/ attribute relationships which can aid the commander by identifying the more important decisions he makes or could make.

The analyst must in some way confirm that the completed model does in fact represent the true preferences of the decision maker.

If the number of attributes is small, then the analyst may develop a functional design to validate the model. A factorial experiment will validate the model and psychological tests can show that the model does produce the same results as the decision maker's holistic judgement. Unfortunately, the number of questions the analyst must ask if the number of attributes is large becomes quite large. For example for five attributes using only two levels, at least $2^5 - 2 =$ 30 holistic judgements must be made. Clearly this method cannot be used for organizational models having 5 or more attributes.

A less reliable approach is convergent validity. The decision maker makes his decision for some example and this result is compared to the model prediction. If the two are dissimilar, an investigation is made into the model and the decision maker's response to determine the error. Again, this approach is limited to about ten factors.

One other approach has been tried using experts. Several experts are asked to select alternatives holistically and by their model. If

most of the variance is attributed to differences in alternatives, then the models are believed to be accurate. This approach is being developed to validate the results of this study.

Another approach is to decompose the bilinear model such that Y_1 = $(X_1 \ldots X_n)$ and $Y_2 = (X_1 \ldots X_m)$ where Y_1 and Y_2 are additive independent. The analyst would then use the functional or correlation approach on (Y_1) and (Y_2) independently. Finally, the analyst would try to validate $u(Y_1)$ and $u(Y_2)$ together.

Once the number of factors exceeds ten, any procedure will be subject to criticism because we have no reference by which to judge. The model we develop <u>is</u> the reference, but the human mind is unable to consider more than ten competing attributes. This situation might be considered an analyst's "Catch 22". At any rate the insights gained into the decision problem may be of value and obvious modeling errors are detectable by "intuitive" validation. Fortunately even in large organizations, most decisions effect only a limited number of attributes; therefore, giving the analyst validation information.

Project Utility Function

Under the assumptions of preferential and utility independence, it followed from the utility theory results reported by Keeney (24) that the project utility function, u(x), should be of the form

$$u(x) = \sum_{i=1}^{n} k_i u_i(x_i) \qquad (4.1)$$

or

$$1 + ku(x) = \sum_{i=1}^{n} (1 + kk_i u_i(x_i)) \qquad (4.2)$$

where u and the u_i are utility functions scaled from zero to one, n is the number of attributes, the k_i are scaling constants with $0 < k_i < 1$, and $k_i > -1$ is a nonzero scaling constant. Equation 4.1 is referred to as the additive utility function and it is appropriate whenever

$$\sum_{i=1}^{n} k_i \neq 1$$

The least and most desirable levels of attribute X are x and x*, respectively, then it follows that the individual utility functions were scaled such that

$$u_i(x_i) = 0 \qquad (4.3)$$

and

$$u_i(x_i^*) = 1 \qquad (4.4)$$

Furthermore, the use of equations (43) and (4.4) in either equation (4.1) or equation (4.2) yields

$$u(x_i^*,\bar{x}_i^\circ) = u(x_1^\circ,\ldots,x_i^\circ-1,x_i^*,x_i^\circ+1,\ldots,x_n^\circ) = k_i \tag{4.5}$$

This latter result means that the scaling constants k_i are simply the probabilities p_i such that the evaluator is indifferent between $(x_i^*,\bar{x}_i^\circ)$ for certain and a lottery yielding either x^* with probability p_i or x° with probability $(1-p_i)$. (For details see Table 10, Chapter VIII.)

Determination of Weighting Constants k_i

The equivalence of k_i and p_i from an appropriate lottery determination as discussed with equation 4.5 was used as a technique to determine the k_i values from the decision maker. Seven different lotteries were posed to the decision maker, one for each attribute, and he was asked to choose the p_i values. The evaluator was told that there was no requirement for the sum of the p_i's to be one and that he should not be concerned about this.

Determine of k

By evaluating equation 4.2 at x^* and using the results of equation 4.4, it follows that

$$1 + k = \sum_{i=1}^{n} (1 + kk_i). \tag{4.6}$$

Keeney [25] shows that if $\sum_{i=1}^{n} k_i > 1$, then $-1 < k < 0$, and if $\sum_{i=1}^{n} k_i < 1$, then $k > 0$. An iterative procedure of estimating a value of k, determining which side of equation 4.6 is larger, and improving the estimate until the two sides are equal is recommended. Such a procedure was programmed and utilized in this application.

Determination of Project Utility Functions

The utility functions are summarized in the next chapter with a complete summary of all the attributes and constants used in the models.

IV. RESULTS

The decision makers at 19th Bomber Wing involved in this study are at the first level of supervision. The analysts interacted with the decision makers in sessions over a time period of approximately eight months.

Throughout this process the analysts encouraged the development of a minimally complete and "independent" set of attributes. The analysts posed questions concerning the meaning of attributes and the nature of scales upon which projects could be rated for each attribute. While the decision maker was already familiar with probabilistic independence, the analysts gave elementary examples of preferential and utility independence as guidance. Despite the encouragement given by the analysts for selecting "independent" attributes, the decision maker was told to always hold firm to any selection for which he felt strongly committed. The final attribute list as presented herein has truly been evolutionary throughout the study and has been of some concern in every session between the decision maker and the analysts.

It was found to be necessary to use hierarchical approaches [10] in going from broad objectives to specific attributes.

a) DCM Attributes

The following eleven attributes were identified for the DCM as being important to the effectiveness of his wing.

112) Sortie proficiency is the rating of sorties flown to those scheduled. As most sortie aborts or cancellations are due to maintenance, the percent flown is a strong measure of maintenance effectiveness.

111) Availability is the number of aircraft physically at Robins AFB compared to the number assigned. Periodically aircraft must be thoroughly gone over by a special maintenance unit.

121) Timely parts supply is the time it takes to receive an item after that item is required. The percent of maintenance jobs deferred for parts measures the timeliness.

122) Quality parts is the condition of a repair part when received. If the part does not work or must be repaired before use, it reduces effectiveness. The percent failed measures this attribute.

21) Training is the training for repair. Training is necessary to assure qualified people to replace those leaving and to assure new items are properly maintained. The perecent unqualified on the MSEP score measures the effectiveness of training.

221) Morale is measured on a 0 to 10 ranking by the DCM.

222) Environment is the condition either controlled or uncontrolled under which the men must work. It is measured by the percent of time the men work in a controlled environment.

23) Manning is the effective utilization of time by the maintenance personnel. It is measured by the percent of hours on the job to the percent available.

24) Safety is measured by the maintenance man-days lost due to accidents on or off the job.

31) Budget effectiveness is measured by the percent of money received to the money requested.

32) Overall effectiveness of the use of money is measured by the cost per aircraft hour.

b) <u>AMS Attributes</u>

The Avionics Maintenance Squadron Commander indicated that fourteen attributes were necessary to determine overall effectiveness of the squadron. More emphasis was placed on skill level and repair equipment than the DCM indicated.

111) Equipment well repaired is measured by the percent of the equipment that cannot be used.

112) Test equipment available refers to required test equipment to do properly and quickly AMS tests. Only AMS considered this as important.

121) Timely parts is the same as the DCM except that measure was in days for delivery.

122) Quality parts is the same as the DCM.

13) Floor space is self explanatory and is measured by the percent of need.

21) Safety is man days lost per month.

22) Manning is the assigned to authorized personnel. Note that this definition differs from the DCM.

2221, 2222, 2223) The number of months each skill level has on the same type system is considered important to proper maintenance.

23) Work load is the hours per week personnel must work.

241, 242) Correct and timely information from air crews and among repairmen is important out to effectiveness. Each is measured on a scale of 0 to 10.

3) Money is measured by the actual to requested.

c) OMS Attributes

The Organizational Maintenance Squadron had eleven attributes.

111) Aborts and cancellations is roughly equivalent to the DCM's sortie proficiency. The measure was percent per quarter.

112) Sorties per month is a measure of the level of activity.

121, 122) Timely and quality parts are the same as the DCM.

131) Aircarft parking is another measure of space on the basis of space per aircraft. Note that some aircarft must be parked on taxi strips.

132) Inspection facilities is the OMS need for space and is measured by number.

211) PRP is the personnel reliability to perform on nuclear weapons and is measured by the proportion qualified.

212) Manning is definea as assigned to authorized.

2131, 2132) Skill levels 7 and 5 were considered critical, but skill level 3 was not.

23) Flight line communications is the ability to communicate by vehicle to aircraft along the flight line.

d) FMS Attributes

The Field Maintenance Squadron commander identified 19 attributes.

111) Red x is a maintenance action which grounds the aircraft until repaired and is measured by the percent of aircraft with red x's.

112) Diagonal is a maintenance action which does not ground the aircraft and is measured by the percent of aircraft with diagonals.

121) Ground equipment is equipment required by the Field Maintenance Squadron and is measured by the percent out.

122) Test equipment is equipment required to determine what caused a failure and is measured by percent out.

131, 132, 133) Aircraft to hangars, test cells, and corrosion facilities are measures of the quantity and quality of the space provided.

211) Manning is again defined as assigned to authorized.

212) Training of craftsmen is again important and is measured by failures per month.

2131, 2132, 2133) Skill level for 7, 5, and 3's is important to the Field Maintenance Squadron as well as the other squadrons.

22) Squadron morale is measured by the number of complaints per 250 people per year.

221) Working conditions is measured on a subjective scale of 0 to 10.

222) Living conditions is measured on a subjective measure on a scale of 0 to 10.

23) Safety is again defined as man days lost to in house or free time accidents.

24) Supervisors is an attribute which relates to how well the supervisor does his job and is measured by repeat write ups per week.

3) Money is again defined as funded to requested.

4) Environment for Field Maintenance refers to the number of fuel spills per quarter.

All three squadrons had to have repair and test equipment. The percent out on each of test, repair, and communication equipment measured the ability of squadrons to repair an aircraft.

All four commanders cited timely parts of the proper quality as vital to effectiveness.

All four commanders agree that facilities of the right type with adequate space was an important factor in effective maintenance. The particular measures varied from detailed types of space to the overall amount and quality as measured.

Within the second major factor of personnel, all four commanders agree that safety, manpower, and morale, and communications were important.

The measures within safety were man days lost for all four; however, the distinction between air crew and maintenance crew was most common.

Under manpower only one commander was concerned with PRP and only one with supervision. All four agree the training and experience of 7 and 5 levels were very important.

All four commanders had morale as a factor but the measures and importance varied considerably. The analyst broke morale into working conditions, living conditions, and working hours.

The three squadron commanders agree that communication within the squadron is important and two commanders wanted good communication with the air crew.

All four commanders agree the funded to requested budget was important to the overall effectiveness. Only the DCM cited cost per aircraft hour as a measure of overall effectiveness.

Inspections were not regarded as an element of effectiveness even though they were mentioned initially be two of the squadron commanders. Later inter-views revealed the commanders considered inspections to be a function of other

factors already included.

While complete unanimity was not present among the commanders, the overall list of factors seems to suggest that individual utility models in SAC may be more transferable than originally believed by the analyst. The hypothesis that these models are transferable needs to be tested on a broader scale.

Utility functions for the individual attributes were developed for the decision maker by arbitrarily assigning utility values of 0 and 1 to the smallest and largest scale values, respectively, and then determining intermediate values were developed questions and comments were posed in an effort to be sure the evaluator understood the assignments. The results of the process are exhibited in Appendix A.

This now brings us to some of the findings of this study besides the original aim to determine the factors of maintenance.

All four SAC commanders aggreed that the utility would decrease if the experienced people now leaving were not replaced by experienced people. They went so far as to say they didn't want inexperienced people. If they were forced to take in inexperienced people, then more time would be taken away from the experienced peo0le to train. Performance levels are high in SAC but the situation is deteriorating rapidly and will continue to do so over the short term regardless of <u>any</u> action taken at <u>any</u> level. It would lessen the rate if transfers of people in and out of SAC were reduced.

All agreed the higher reliability of equipment would lesses the need for manpower. One such example was a radio with MTBF of 14 hours lengthened to over 200 hours. The repairmen were reduced from 12 to 5 without loss. Such improvements in reliab[illegible] and reduced complexity would help the manpower situation.

Also all agreed that the Division level in SAC could be eliminated without loss. In fact if the experienced people were sent to the wings some improvement of effectiveness might result.

Table 1

a. DCM - The DCM model is as follows

$$U_{DCM}(X) = .4\{[1 + .5(.5U(X_{111}) + .3U(X_{112}) + .2U(X_{111})U(X_{112}))]$$
$$[1 + .5(.4U(X_{121}) + .4U(X_{122}) + .2U(X_{121})U(X_{122}))]-1\}/1.25$$
$$+ .5[.3U(X_{21})+.15(.2U(X_{221})+.2U(X_{222})+.6U(X_{221})U(X_{222}))$$
$$+ .4U(X_{23}) + .15U(X_{24})]$$
$$+ .1[.4U(X_{31}) + .2U(X_{32}) + .4U(X_{31})U(X_{32})]$$

$$U_{DCM}(X) = .40951$$

b. AMS - The AMS model is as follows

$$U_{AMS}(X) = \frac{\prod_{i=1}^{n} (1 + kk_i U_i(X_i)) - 1}{k}$$

where k = -.95235.

$$U_{AMS}(X) = .93285$$

c. OMS - The OMS model is as follows

$$U_{OMS}(X) = \frac{\prod_{i=1}^{n} (1 + kk_i U_i(X_i)) - 1}{k}$$

where k = -.97992.

$$U_{OMS}(X) = .67687$$

d. FMS - The FMS model is as follows

$$U_{FMS}(X) = \frac{\prod_{i=1}^{n} (1 + kk_i U_i(X_i)) - 1}{k}$$

where k = -.98761

$$U_{FMS}(X) = .9279$$

V. Use and Implementation

After expending the effort to develop a model, it should be utilized. The only reason for doing such an exercise is to aid the decision maker in analyzing complex decisions.

The first use of the process is to gain insight into the decision to be made. Even if no model was created, the thought and consideration given to the decision should improve that decision. The second use of this tool is an aid in actual decision making. The third use is to help formulate an argument or a position paper on some subject. The greatest use of the theory is probably for one time decisions; however, in continuing systems the third use may prove to be of great value. The use of the model as an aid in making decisions on flextime and manpower experience is given in Appendix C.

A fourth use of the model is to give a reading of the current effectiveness of an organization by means of a value of the utility function as recomputed periodically.

Decision Aid

The utility model helps a decision maker gain insight into the decision he must make. By pinpointing the conflicts and the importance of those conflicts, he is better able to make a sound and reasoned decision. As such the model is an aid to decision making.

No decision maker should place complete reliance on such a tool since the model is derived using subjective attributes, focus, and weights. Where holistic judgement does not agree with the model, the decision maker should consider why there is a difference. Perhaps the model should be modified or perhaps his holestic judgement did not account for all the attributes and their relations. The decision maker is responsible for his decision whichever he chooses to follow.

Position Paper

The greatest use of the utility model in the Air Force is to use it as a guide in evaluating alternatives rather than to use the results to argue the pros and cons of each alternative.

A general focus of a talk to convince is to cite a specific case symtomatic of the problem, then to show that the problem is general in nature. This procedure should generate enough interest to allow a statement of the point or course of action. Next the briefer must cite what would happen if his recommendation is followed. The utility approach provides arguments for the adoption. Next the speaker must answer anticipated objections. Again, utility theory will provide material in an organized way. Finally the conditions that would exist if the recommendations were adopted can be estimated.

Basically the whole process permits a tightly reasoned argument for some position whether presented orally or in writing.

Two position memos are shown in Appendix C to illustrate the type of reasoning. The first of these positions is a recommendation to continue flextime. Note that this recommendation applies only to SD under the decision maker. A different organization or the same organization under a different commander might yield a completely different answer and both would be correct on an objective basis.

Effectiveness Clock

Over a period of time is the decision maker improving his organization? Periodically, he may wish to evaluate all attributes and compare to the value of the attributes. As the first derivative would guide the decision maker to the factors which would yield the greatest improvement, the decision maker may wish to start a program to improve that area.

Another area not to be overlooked is to identify how the people reporting to the decision maker effect the clock. A careful analysis would show the maximum value at which the decision maker could operate his organization. The decision maker could take the greatest restraint times the probabilty of removal for arguing in a position statement.

The present value of the effectiveness clock for Col Lindsay and Mr Thoreen is shown in Appendix D. Any change either from within, from outside, or by deliberate decision may effect this value. For

example, a busy employee may retire thus lowering the value. The question for the decision maker is what steps to take to replace this man and raise his organization's effectiveness back to the level attained prior to retirement. In this way the effectiveness clock may be used to spot developing troubles and correct them before serious erosion can occur.

By the use of the above type of model, the static model developed in this report could become a dynamic model. The decision maker should note that what improves effectiveness on a one time occurrence may have the opposite effect on a continuing policy. For example, granting a single parent permission to be excused from TDY once may improve organization effectiveness; but if it were policy to excuse single parents from TDY, the effectiveness of the unit might be lowered.

Transferability

Does a model transfer to a new decision maker performing the same job? The answer to this question is unknown for Air Force organizations. The high degree of structure in the Air Force leads one to suspect that at the higher levels in the hierarchy, the factors would be the same. The individual attributes may have some commonality, but the weight given various factors will probably differ.

If the Air Force desired to have commanders use this tool as an aid in decision making, how should it be implemented? The following are some suggestions for implementing the model.

First the commander must be briefed about what utility theory is and what it will do for him. The commander must understand that it will help him, but that the model does not replace his decision making.

After briefing the commander, the problem should be stated. For organizational effectiveness the problem is to maintain the effectiveness of the organization at as high a level as possible. The problem statement should go on to state the particular decision of the organization and the environment in which the organization works.

Next the commander, with the aid of the analyst, should go through the "quick procedure" shown in Table 2 and a guide to trade-offs shown in Table 3. This "quick procedure" will take four to six one hour sessions depending on several factors such as desire of the commander to discuss his situation, grasp of utility models, technical background, etc. A period of pragmatic validation is required to determine how well this model reflects the real feelings of the decision maker. Actual decisions on positions are used to judge holistic

TABLE 2

QUICK PROCEDURE

1. Brief Decision Maker

2. State Problem

3. Identify Factors

4. Identify Utility Function for Each Factor

5. Weight Factors

6. Check Assumptions

    a. Utility

    b. Preferential Independence

    c. Parametric Dependence

    d. Bell's Procedure

    e. Additivity

7. Formulate Model

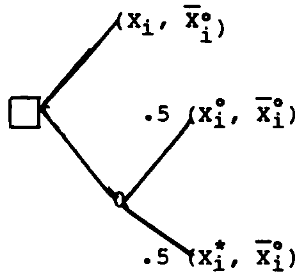
8. Validate Model

9. Check Uncertainty

TABLE 3

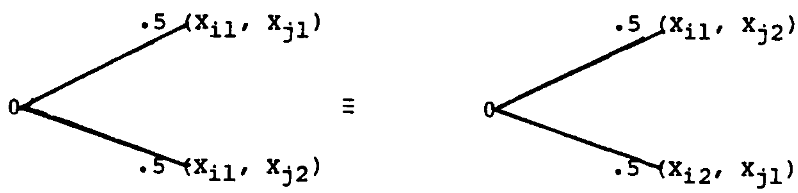
GUIDE TO LOTTERIES

(1) Utility Independence

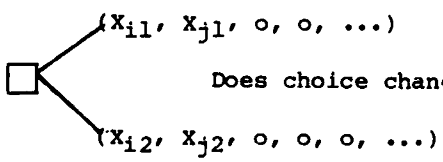


Does x_i change when $\bar{x}_i^\circ$ changed to $\bar{x}_i^*$?

(2) Additive Independence



(3) Preferential



Does choice change for

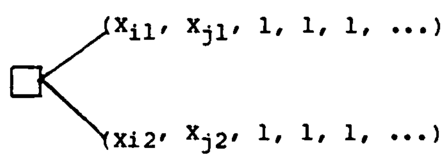
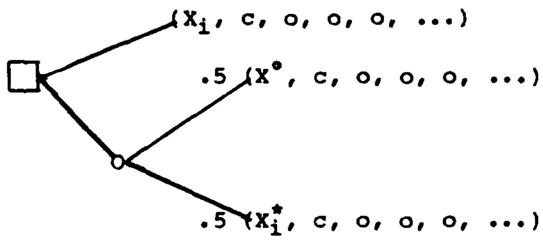


TABLE 3 - GUIDE TO LOTTERIES (Cont'd)

(4) Conditional Utility Independence

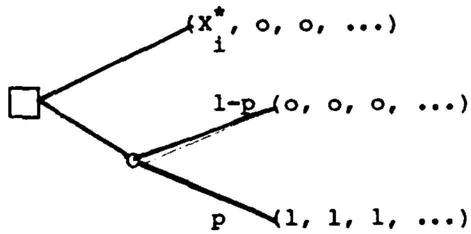


Let $X_i = c$

Does X_i change if o changed to 1?

Does x_i change if c changed to c' and above was utility independent? If so X_i is conditional utility independent of X_j.

(5) Rank Weights



For that value of p for which the decisio maker is indifferent let $w_i = p$.

vs model similarity. Differences must be accounted for during validation.

Finally, the results are put into a routine system either manually or interactive on the computer as illustrated in Appendices D and F.

Manual Computation (refer to Appendix D for Tables)

The manual procedure consists of using three tables to compute the various utility functions in the hierarchy. Step one is to examine the current values in Table 4. The decision maker then decides whether a contemplated act will change the level of the attribute. He may wish to refer to the attribute utility functions listed in Appendix D. The next to the last column of Table 4 is the new value of the factor and the last column is the new value of the utility function as calculated by the formula or read off the graph.

Step two is to use the utility values found in step one to compute all the utility values in the hierarchy using the model given in Table 5. Step three is optional as it consists of expanding Table 2 by summarizing all utility values into it. A tabulation which may be used in the report or presentation results.

Step four is to examine the resulting utility values carefully to determine if it coincides with the intuitive feel of the decision maker. If it does not agree, the decision maker should ask if the disagreement is in his judgement or the model to answer this question

each attribute must be must be carefully examined. If the difficulty cannot be resolved the decision maker goes to step five.

Step five is to call the analyst in to help find the difficulty. The trouble could be in the model or some inconsistencey in the decision maker.

Computer Interaction

The computer steps are precisely the same as the manual steps except the decision maker must go to a computer terminal. Exact steps are given in Appendix B.

The principle advantage of the computer is to allow the decision maker to examine the improvement in utility of any given decision. This flexibility permits many decisions to be examined and the sensitivity determined.

Interpretation of Output

Typical output of the computer is shown in Appendix F. The utility (U) values are summarized along with their percent change for each factor in the hierarchy. The percent change is a reflection of the subjective feelings of the decision maker. As such the decision maker should critically examine all the changes to determine if his overall judgement agrees. If it does not, then he needs to examine the process to determine where his true feelings differ from the model results.

Sources of error can come from several assumptions.

1. The value of the attribute utilities may be incorrect.

2. A factor may be missing.

3. The independence assumptions may have been incorrectly assumed.

4. The form of individual attribute utility functions or their limits may be in error.

Only after the decision maker satisfies himself that his utility values are reflecting his own feelings and perhaps the objective data, should he proceed to make a decision or advance a position.

Uncertainty

In this study the most likely value for an attribute was chosen for development of the utility function. Very formally the model would be called value or worth function as uncertainty was not built into the attribute utility functions. Nevertheless, the model as formulated could easily incorporate uncertainty into it. For example, if the decision maker says morale is 6 on a scale of 10, the analyst could ask for highest and lowest values. If the decision maker says 7 and 5, the analyst could assume normality with mean 6 and a standard deviation of one-third.

If the distribution is approximately symmetric, then the results of using the model without uncertainty is approximately correct. If the distribution is very unsymmetric, we may need to use the expected value.

If the decision maker is interested in the range of outcomes rather than the expected value, then uncertainty should be assessed for this computation. As the uncertainty process is somewhat lengthy, it is normally omitted on the initial development of the utility model.

Policy Formulation

This study did not attempt to address the question of policy formulation to improve utility in the long run. This study took a static short term view, normally less than one year. Further work might be done to determine if the process is a Markov chain with a constant transition matrix. If this were the case, policy might be established using this tool. Indeed, by combining this result with dynamic programming it may be possible to formulate optimal policy.

VI. CONCLUSIONS

Utility theory is an aid to decision making, a method to help construct arguments, and a way to gain insight into problems. As such it is a worthwhile tool for the decision maker. It does not replace the responsibility of the decision maker to examine all the facts and render his decision.

The decision maker in this process has an opportunity to reflect on what is important in the effectiveness of the organization. This process alone might justify the use of this tool. Certainly there are many hard tradeoffs to be made before arriving at a conclusion.

The present state of the art calls for those commanders desiring to use this procedure to volunteer to have the analyst set up the model with him. No commander should be directed to develop a model; because the nature of the problem requires complete support of the decision maker. If one is forced to develop a model, he is not likely to use it and thus the exercise would be of no value.

Advantages

The chief advantage of utility theory is that it identifies the important variables and their relationship. When the decision maker is asked to justify his decisions or position, he can state his feelings in more precise terms.

If subordinates disagree with a decision, they may show the decision maker the factors on which they feel he erred. The commander should be able to head off arguments and hard feelings, thereby gaining cooperation for his position.

Likewise when a decision maker advances a position to his superior, they can identify the areas of disagreement more sharply. Perhaps the larger organization has factors not considered by the subordinate organization commander.

Objections

The greatest objection given to utility theory is that it is not transferrable to others. While this is generally true, we can also make the same claim of any decision making process. To do otherwise is to remove the decision from the decision maker. Individual differences must be accepted and each decision maker regarded as different.

Another objection is the time to conduct a study. The quick procedure given here helps overcome this objection; however, all important decisions should be deliverated long and thoughtfully. If a decision is final there is no need for a review of the decision model. If a decision is complex and far reaching, the decision maker should expect to spend time on all facets of his decision.

An additional objection is that the commander should develop policy which will guide his organization to success and effectiveness. More research is needed to develop dynamic utility models. Still another objection is that the subjective model is too imprecise and changes for the decision maker from time to time. The decision maker may want to know how his feelings change. By knowing he may make more rational and less emotional decisions.

Results

Utility models for various commanders   have been formulated to reflect their ideas and thoughts on how to judge the effectivensss of their respective organizations. The models have been programmed to permit fast and accurate estimates of the utility values. The procedures do work.

The decision maker must now decide to use this tool and to determine if it does in fact help him to improve the effectiveness of his organization. At worst the decision made using this tool will differ from his initial feeling and he will have to study the situation only to find the model is incorrect. The process should help the decision maker understand his problem. In some cases the process may help the decision maker make a better decision. In the middle ground the utility model may confirm what he believed to be true, but it should add weight to his argument.

Other than time spent, the process cannot hurt the decision and it may help it. If this process is not used, what else can be used?

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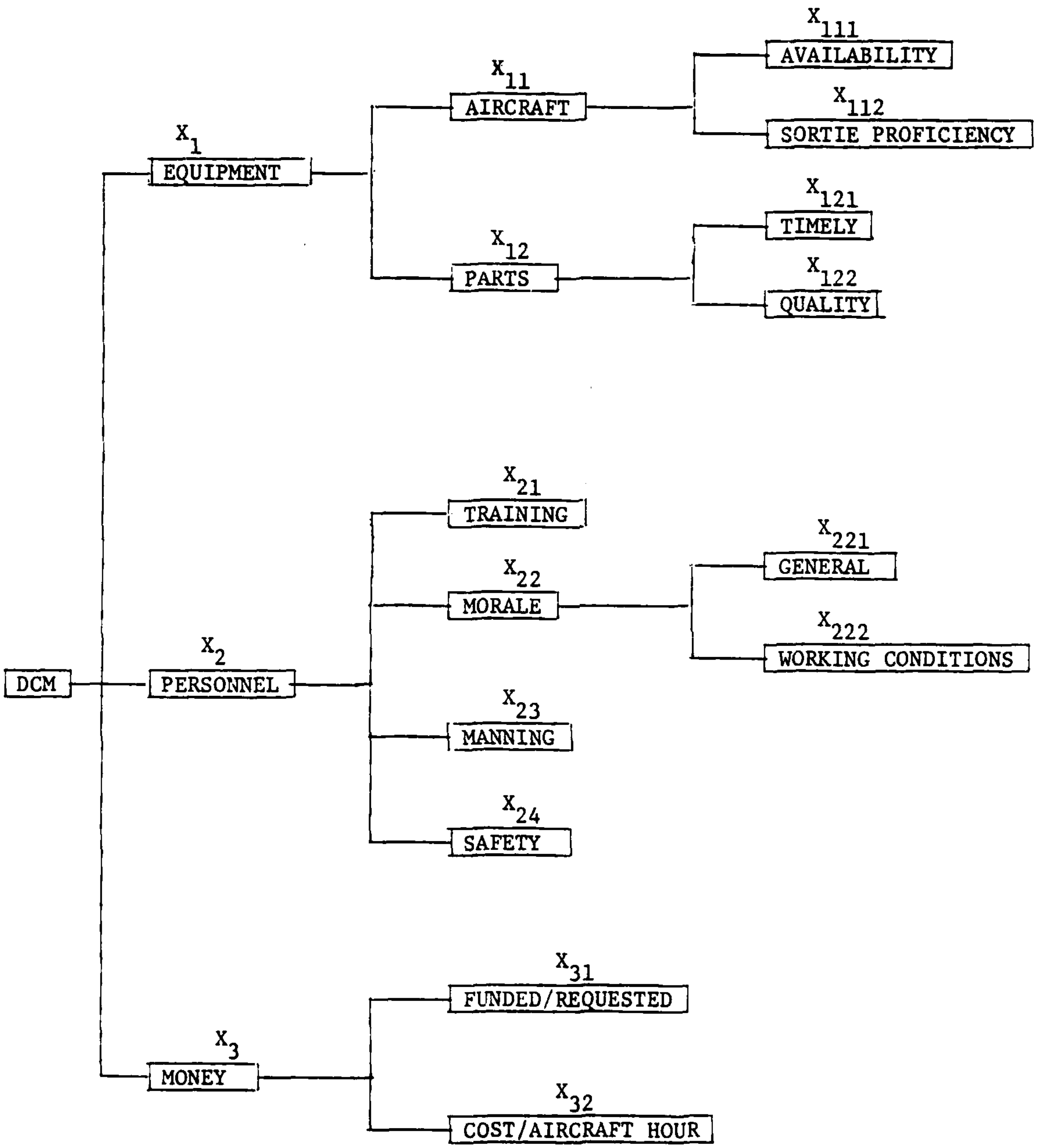
APPENDIX A

UTILITY MODELS

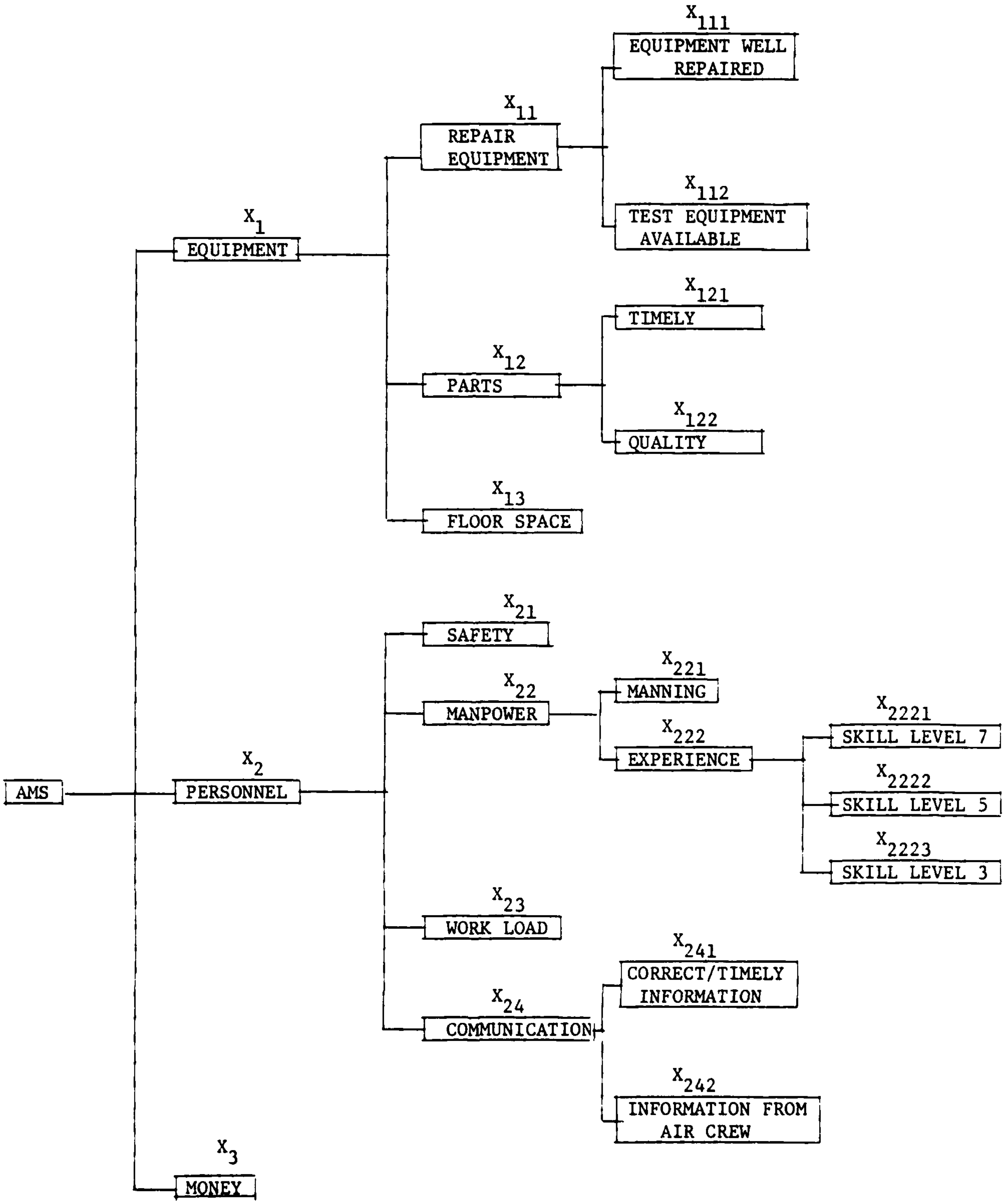
D.C.M. ATTRIBUTE SET



D.C.M.

Name	Attribute Number	Units	Range	K_i	Current Status	
Availability	X_{111}	AC here/ assigned	$92\text{-}100_{B52}$ $80\text{-}100_{135}$	.06	93	$U(X_{111}) = .0625[X_{B52}-92] + .025[X_{135} - 80]$
Sortie Proficiency	X_{112}	% flew/ scheduled	92-100	.1	95	$U(X_{112}) = 1,\ X_{112} = 100$ $U(X_{112}) = 0,\ X_{112} < 100$
Parts Timely	X_{121}	% deferred	0-10	.08	5	$U(X_{121}) = .1[10-X_{121}]$
Parts Quality	X_{122}	% failed	0-10	.08	6	$U(X_{122}) = -.1\ X_{122} + 1$
Training	X_{21}	% unqual. MSEP score	0-20	.15	15	$U(X_{21}) = .05[20 - X_{21}]$
Morale	X_{221}	-	0-10	.015	8	$U(X_{221}) = .1\ X_{221}$
Working Conditions	X_{222}	% of time	0-100	.015	57	$U(X_{222}) = .01\ X_{222}$
Manning	X_{23}	% hrs. on job/ hrs. avail.	50-70	.2	60	$U(X_{23}) = .05[X_{23} - 50]$
Safety	X_{24}	Man-days lost	0-3	.075	0	$U(X_{24}) = 1 - .3333\ X_{24}$
Funded/Requested	X_{31}	% received/ requested	85-100	.04	85	$U(X_{31}) = -1/225(100 - X_{31})^2 + 1$
Cost/Aircraft Hour	X_{32}	Cost per AC hour	\$200-\$400	.02	227	$U(X_{32}) = -1/40000(X_{32} - 200)^2 + 1$

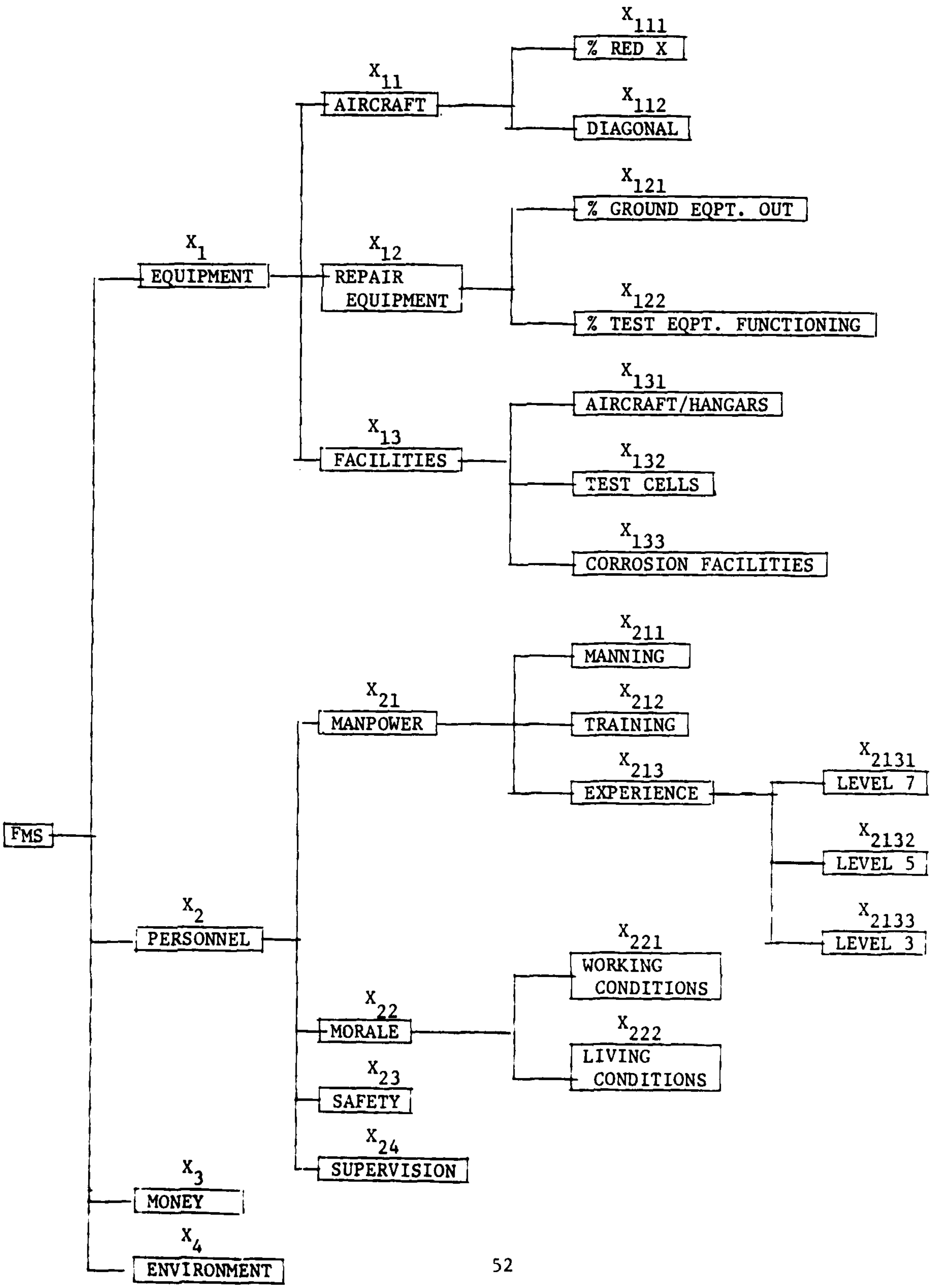
A.M.S. ATTRIBUTE SET



A.M.S.

Name	Attribute Number	Units	Range	K_i	Current Status	Utility Function
Equipment Well Repaired	X_{111}	%	0-20	.25	5	$U(X_{111}) = .05\ [20 - X_{111}]$
Test Eqpt. Available	X_{112}	%	70-100	.35	96	$U(X_{112}) = .0333[X_{112} - 70]$
Parts Timely	X_{121}	Days	0-30	.07	4	$U(X_{121}) = .0333[30 - X_{121}]$
Parts Quality	X_{122}	%	0-25	.08	3	$U(X_{122}) = .04[25 - X_{122}]$
Floor Space	X_{13}	Now/Needed	0-1	.05	1	$U(X_{13}) = X_{13}$
Safety	X_{21}	Man days lost/month	0-4	.40	1	$U(X_{21}) = .25[4 - X_{21}]$
Manning	X_{221}	Assigned/Authorized	0.8-1	.15	.9	$U(X_{221}) = 5[X_{221} - .8]$
Skill Level 7	X_{2221}	Months	24-60	.35	40	$U(X_{2221}) = .0278[X_{2221}-24]$
Skill Level 5	X_{2222}	Months	12-24	.20	18	$U(X_{2222}) = .0833[X_{2222}-12]$
Skill Level 3	X_{2223}	Months	6-12	.10	7	$U(X_{2223})=.1667[X_{2223}-6]$
Work Load	X_{23}	Hours/Week	40-50	.25	40	$U(X_{23}) = .1[50 - X_{23}]$
Correct/Timely Information	X_{241}	-	0-10	.03	7.5	$U(X_{241}) = .1\ X_{241}$
Information from Air Crew	X_{242}	-	0-10	.03	6	$U(X_{242}) = .1\ X_{242}$
Money	X_3	Actual/Budget	0.6-1	.40	1	$U(X_3) = 2.5[X_3 - 0.6]$

F.M.S. ATTRIBUTE SET

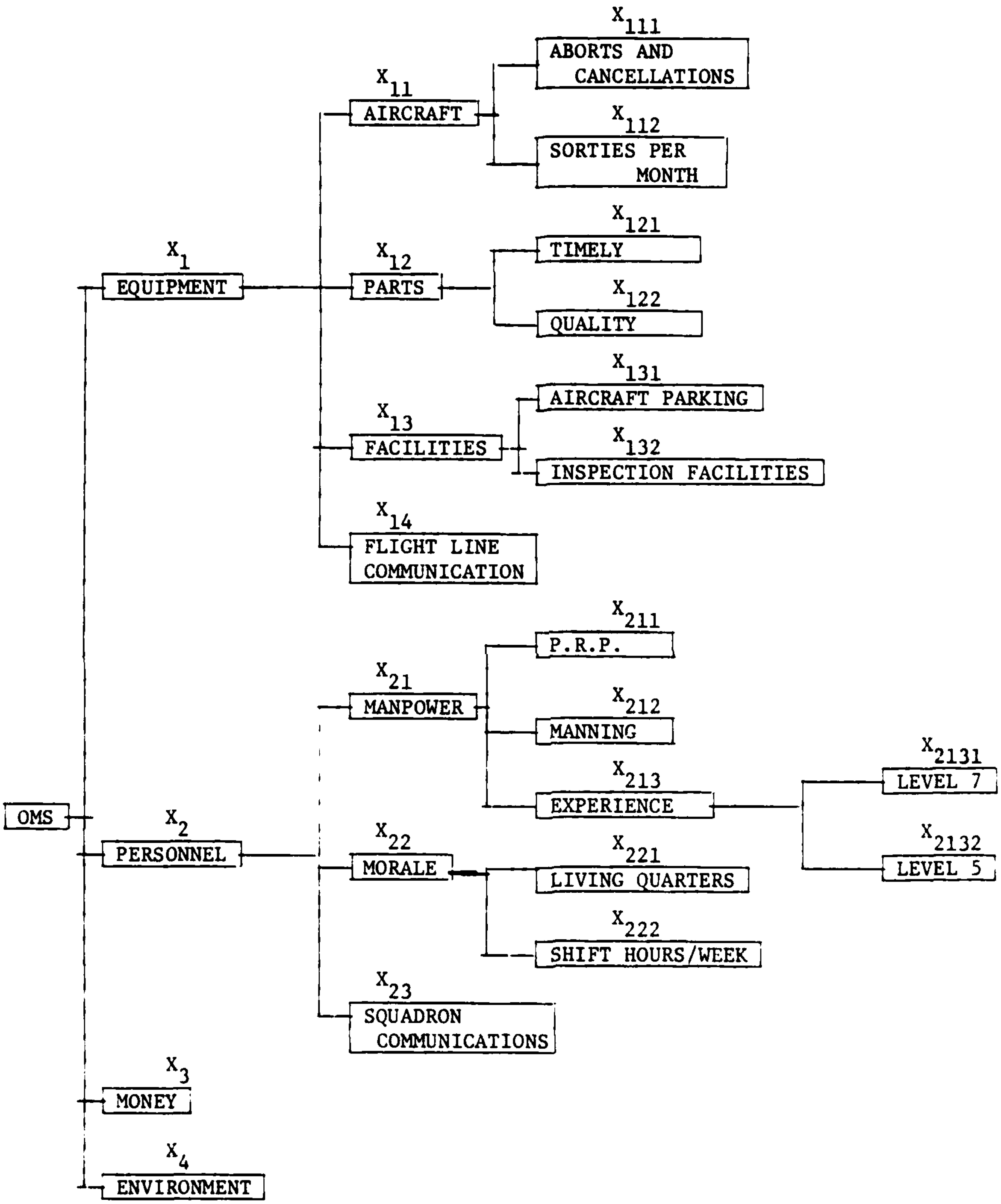


FMS

Name	Attribute Number	Units	Range	K_i	Current Status	Utility Function
% Aircraft - Red X	X_{111}	%	0-35	.30	25	$U(X_{111}) = -.00082[35 - X_{111}]^2 + 1$
% Aircraft - Diagonal	X_{112}	%	0-100	.15	100	$U(X_{112}) = .01[100 - X_{112}]$
% Ground Eqpt. Out	X_{121}	%	0-30	.25	15	$U(X_{121}) = -.0011[30 - X_{121}]^2 + 1$
% Test Eqpt. Funct.	X_{122}	%	90-100	.28	95	$U(X_{122}) = .1[X_{122} - 90]$
Aircraft/hangars ratio	X_{131}	Aircraft/ Hangars	7-9	.15	7	$U(X_{131}) = .5[9 - X_{131}]$
Test Cells	X_{132}	Number	0,1	.30	1	$U(X_{132}) = 0, X_{132} = 0$ $U(X_{132}) = 1, X_{132} = 1$
Corrosion Facilities	X_{133}	Number	0,1	.15	0	$U(X_{133}) = 0, X_{133} = 0$ $U(X_{133}) = 1, X_{133} = 1$
Manning	X_{211}	Assigned/ Authorized	0.8-1	.25	1	$U(X_{211}) = -25(1 - X_{211})^2 + 1$
Training	X_{212}	Failures/mo.	0-1	.10	5/12	$U(X_{212}) = 1 - X_{212}$
Experience Level 7	X_{2131}	Months	12-48	.30	33	$U(X_{2131}) = .00077[X_{2131} - 12]^2$
Experience Level 5	X_{2132}	Months	12-24	.25	18	$U(X_{2132}) = .0069[X_{2132} - 12]^2$
Experience Level 3	X_{2133}	Months	0-12	.05	.8	$U(X_{2133}) = .0069(X_{2133})^2$
Squadron Morale	X_{22}	Complaints/ 250/year	0-8	.07	6	$U(X_{22}) = .125[8 - X_{22}]$

Name	Attribute Number	Units	Range	K_i	Current Status	Utility Function
Working Conditions	X_{221}	-	0-10	.15	8.5	$U(X_{221}) = .1\ X_{221}$
Living Conditions	X_{222}	-	0-10	.25	9	$U(X_{222}) = -\ .01[10 - X_{222}]^2 + 1$
Safety	X_{23}	Man days/ month	0-5	.25	.16	$U(X_{23})\ .2[5 - X_{23}]$
Supervision	X_{24}	Repeat Write ups/wk.	0-10	.25	2.5	$U(X_{24}) = -\ .01[10 - X_{24}]^2 + 1$
Money	X_3	%	90-110	.33	95	$U(X_3) = -.0025[110 - X_3]^2 + 1$
Environment	X_4	Fuel spills/ quarter	0-8	.05	4	$U(X_4) = .125[8 - X_4]$

O.M.S. ATTRIBUTE SET



O.M.S.

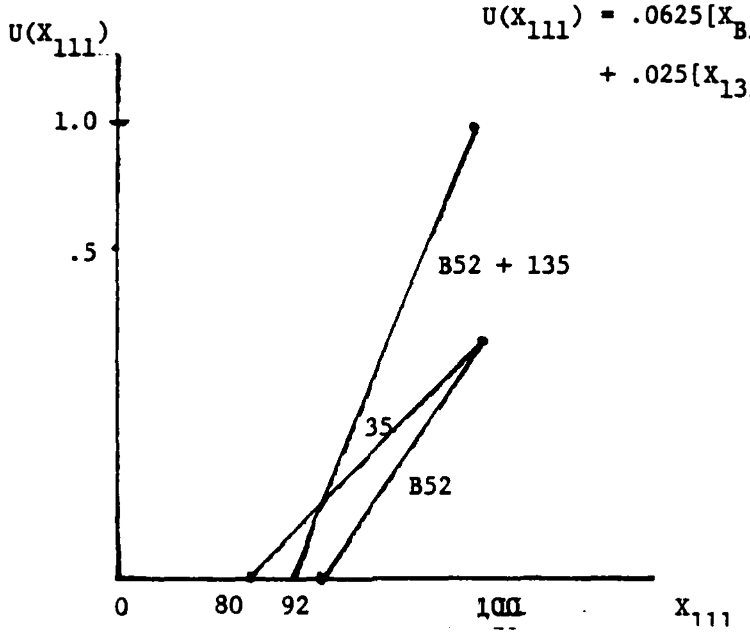
Name	Attribute Number	Units	Range	K_i	Current Status	Utility Function
Aborts and Cancellations	X_{111}	% per quarter	0-4 0-10	.1	5	$U(X_{111}) = .4[.25(4-X_{111})] + .6[-.01 X_{111}^2 + 1]$
Sorties per Month	X_{112}	Sorties per month	72-77	.20	72	$U(X_{112}) = .2[77 - X_{112}]$
Parts Timely	X_{121}	Ave. days	0-30	.10	3	$U(X_{121}) = .0333[30 - X_{121}]$
Parts Quality	X_{122}	% Useable	90-100	.05	90	$U(X_{122}) = .1[X_{122} - 90]$
Aircraft Parking	X_{131}	Spaces/ Aircraft	0-1	.10	12/22	$U(X_{131}) = X_{131}$
Inspection Facilities	X_{132}	Number	2-5	.20	4	$U(X_{132}) = 0,\ X_{132} = 2$ $U(X_{132}) = .2,\ X_{132} = 3$ $U(X_{132}) = .8,\ X_{132} = 4$ $U(X_{132}) = 1,\ X_{132} = 5$
Flight Line Communication	X_{14}	% Vehicles radio equip.	50-100	.10	80	$U(X_{14}) = .02[X_{14} - 50]$
P.R.P.	X_{211}	Proportion Completed	.85-1	.10	.9	$U(X_{211}) = 6.6667[X_{211} - .85]$
Manning	X_{212}	Assigned/ Authorized	.85-1.0	.18	.98	$U(X_{212}) = 6.6667[X_{212} - .85]$
Skill Level 7	X_{2131}	Months	24-60	.20	30	$U(X_{2131}) = 1/1296(X_{2131} - 24)^2$
Skill Level 5	X_{2132}	Months	0-24	.10	18	$U(X_{2132}) = 1/576(X_{2132})^2$
Living Quarters	X_{221}	-	0-10	.08	4	$U(X_{221}) = .1X_{221}$
Shift hours per week	X_{222}	Hours/week	40-60	.10	44	$U(X_{222}) = .05[60 - X_{222}]$
Squadron Communications	X_{23}	-	0-10	.04	8	$U(X_{23}) = .1X_{23}$
Money	X_3	Funded/ Requested	.8-1.1	.9	.85	$U(X_3) = 100/9(X_3 - .8)^2$
Environment	X_4	E.P.A Violations/yr	0-2	.03	1	$U(X_4) = .5[2-X_4]$

Figure 1

D.C.M. Attribute utility functions

Figure 1a

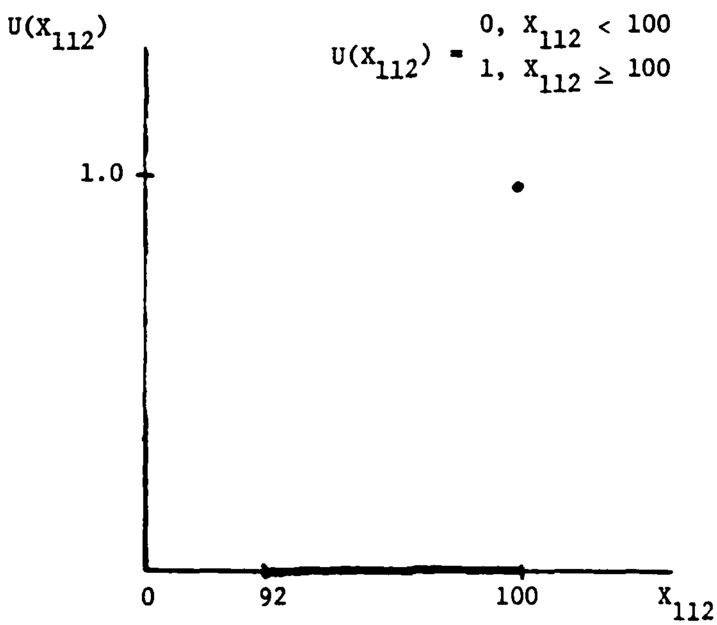
X_{111} Availability



$U(X_{111}) = .0625[X_{B52} - 92] + .025[X_{135} - 80]$

Figure 1b

X_{112} Sortie Proficiency



$$U(X_{112}) = \begin{cases} 0, & X_{112} < 100 \\ 1, & X_{112} \geq 100 \end{cases}$$

Figure 1 (con't)

Figure 1c

X_{121} Parts Timely

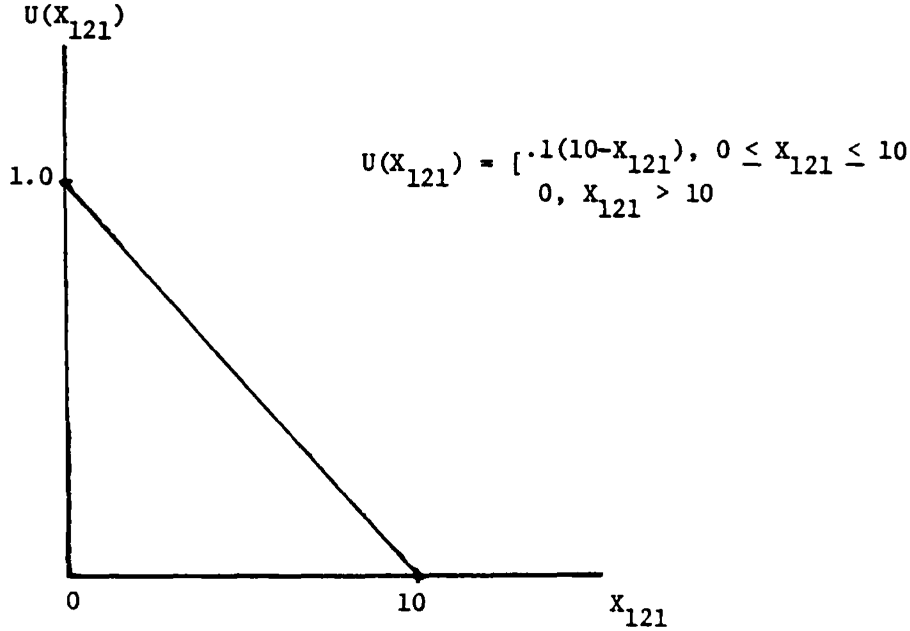


Figure 1d

$U(X_{122})$ X_{122} Parts Quality

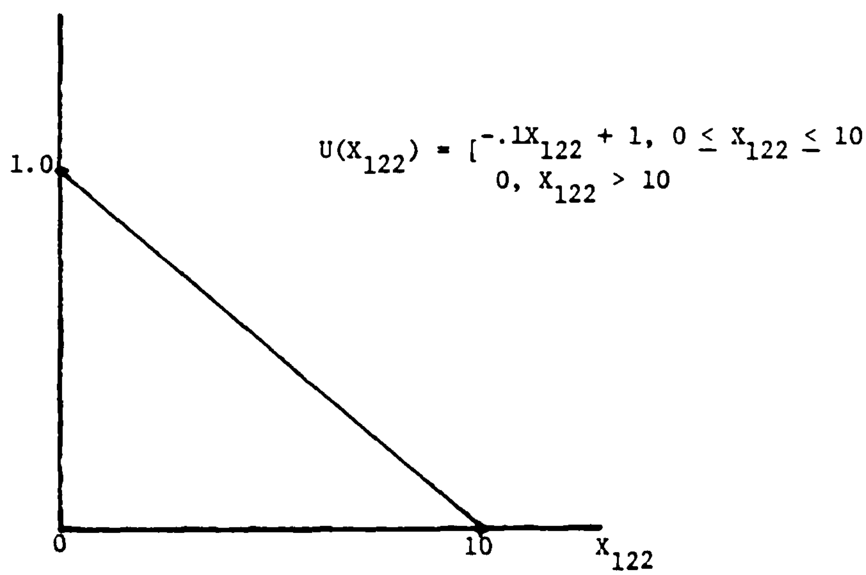
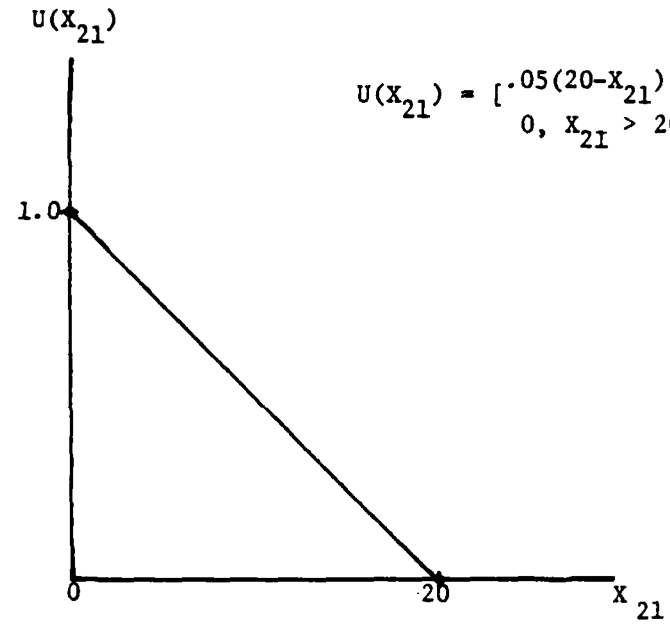


Figure 1 (con't)

Figure 1e

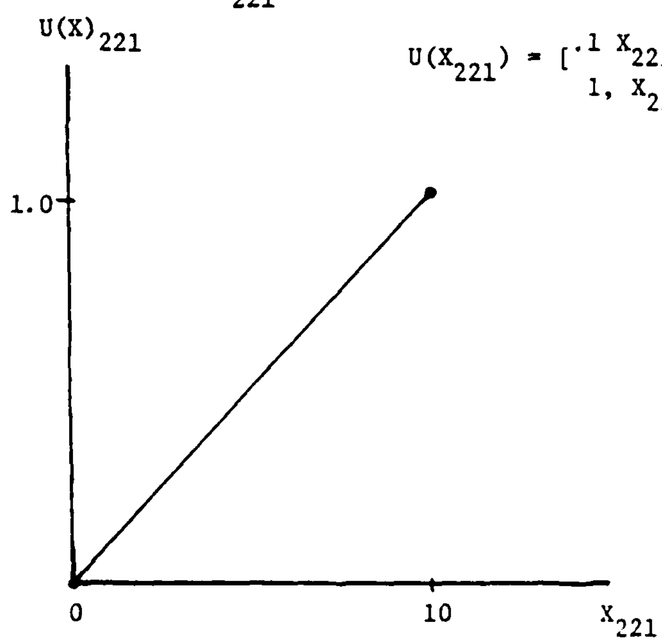
X_{21} Training



$$U(X_{21}) = \begin{cases} .05(20-X_{21}), & 0 \leq X_{21} \leq 20 \\ 0, & X_{21} > 20 \end{cases}$$

Figure 1f

X_{221} Morale

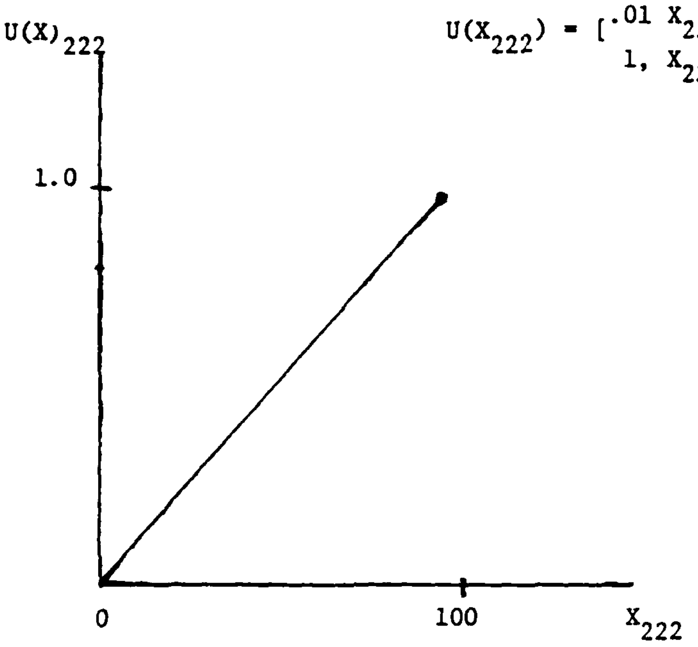


$$U(X_{221}) = \begin{cases} .1\ X_{221}, & X_{221} \leq 10,\ X_{221} \geq 0 \\ 1, & X_{221} > 10 \end{cases}$$

Figure 1 (con't)

X_{222} Environment

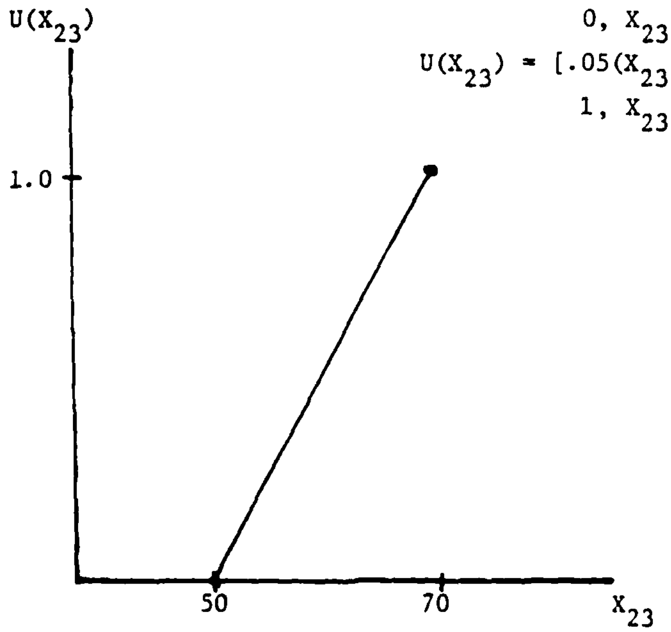
Figure 1g



$$U(X_{222}) = \begin{cases} .01\,X_{222}, & 0 \le X_{222} \le 100 \\ 1, & X_{222} > 100 \end{cases}$$

Figure 1h

X_{23} Manning



$$U(X_{23}) = \begin{cases} 0, & X_{23} < 50 \\ .05(X_{23} - 50), & 50 \le X_{23} \le 70 \\ 1, & X_{23} > 70 \end{cases}$$

Figure 1 (con't)

Figure 1i

X_{24} Safety

$$U(X_{24}) = \begin{cases} 1 - .3333X_{24}, & 0 \le X_{24} \le 3 \\ 0, & X_{24} > 3 \end{cases}$$

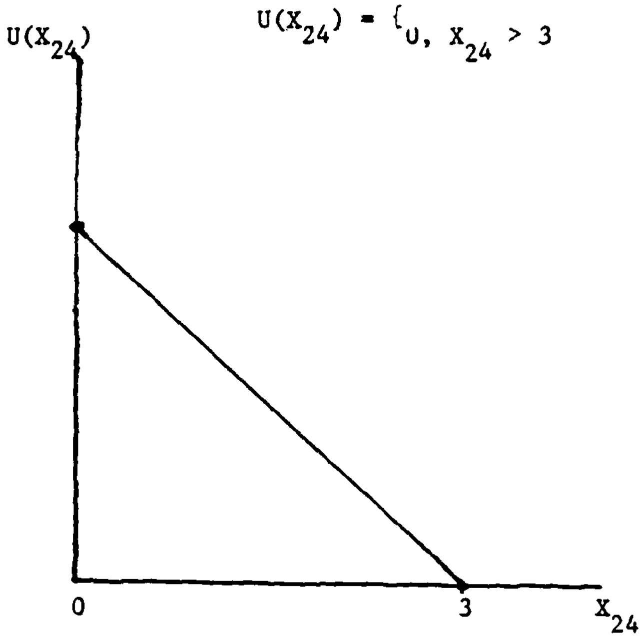


Figure 1j

X_{31} Funded/Requested

$$U(X_{31}) = \begin{cases} 0, & X_{31} < 85 \\ 1/255(100-X_{31})^2+1, & 85 \le X_{31} \le 100 \\ 1, & X_{31} > 100 \end{cases}$$

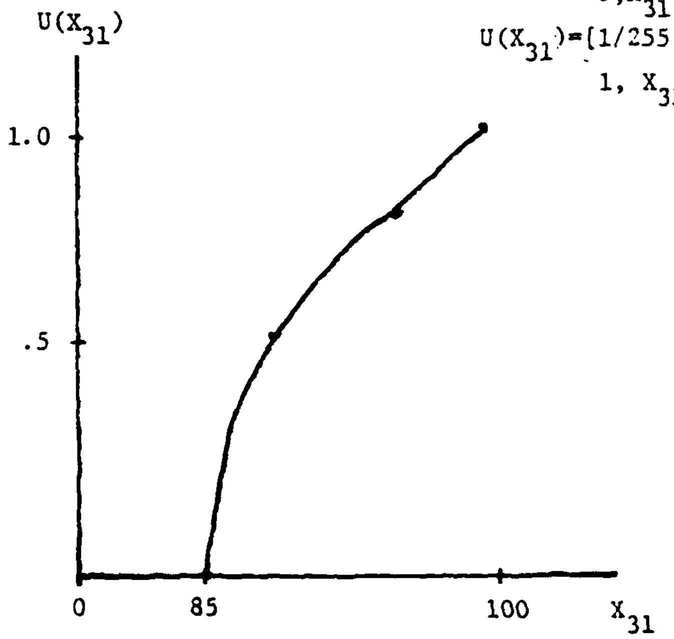


Figure 1 (con't)

Figure 1k

X_{32} Cost/Aircraft Hour

$$U(X_{32}) = \begin{cases} 1, X_{32} < 200 \\ -1/40000(X_{32}-200)^2+1, 200 \le X_{32} \le 400 \\ 0, X_{32} > 400 \end{cases}$$

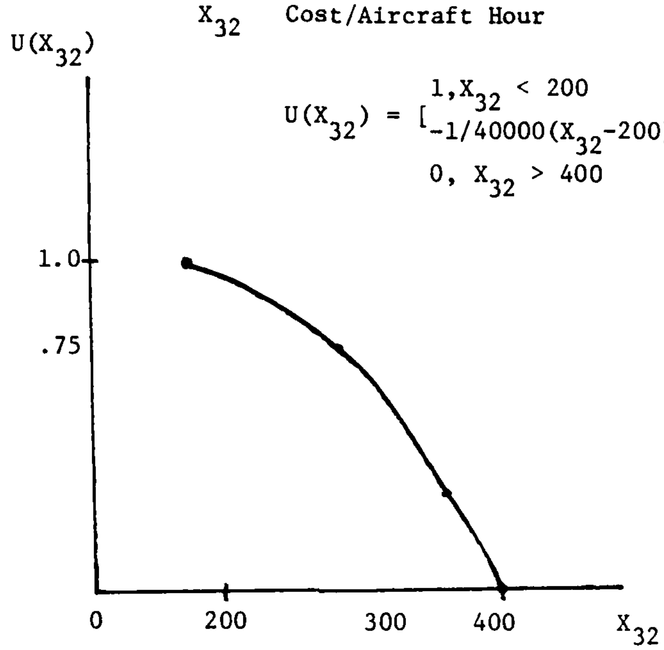
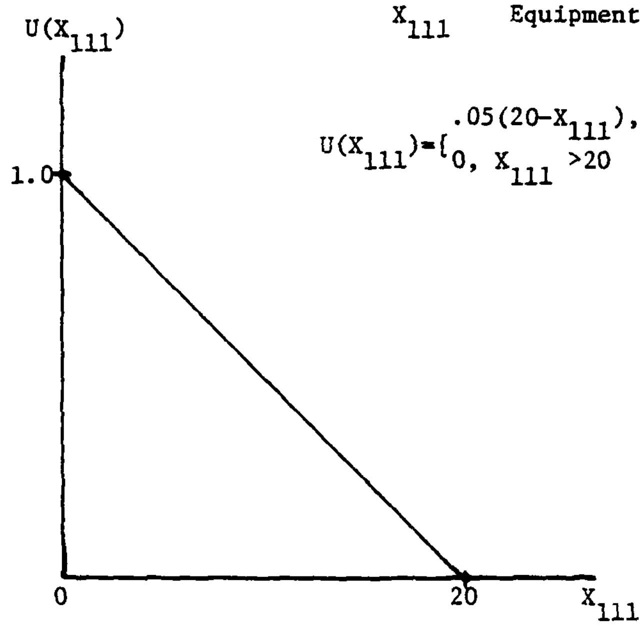


Figure 2

A.M.S. Attribute Utility Functions

Figure 2a

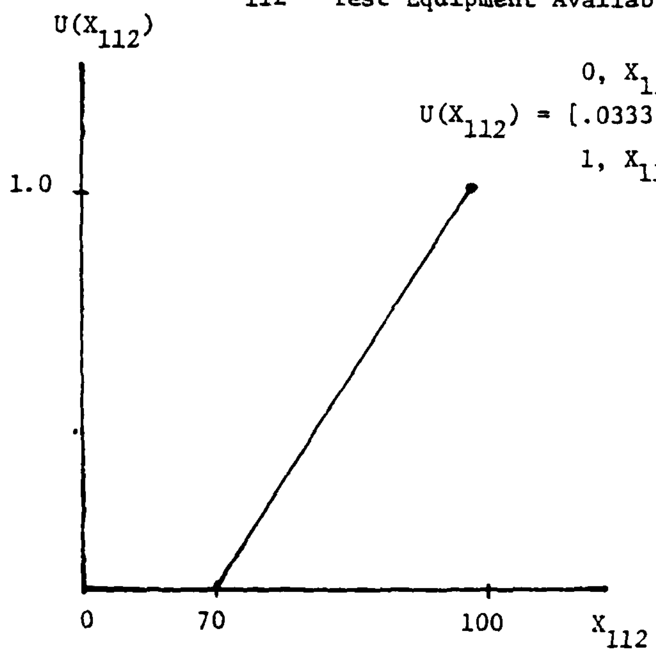
X_{111} Equipment Well Repaired



$$U(X_{111}) = \begin{cases} .05(20-X_{111}), & 0 \leq X_{111} \leq 20 \\ 0, & X_{111} > 20 \end{cases}$$

Figure 2b

X_{112} Test Equipment Available

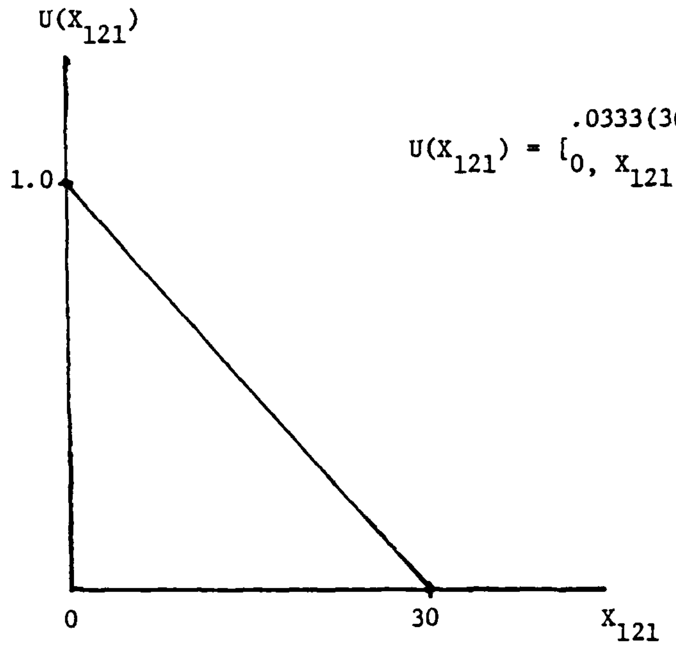


$$U(X_{112}) = \begin{cases} 0, & X_{112} < 70 \\ .0333(X_{112}-70), & 70 \leq X_{112} \leq 100 \\ 1, & X_{112} > 100 \end{cases}$$

Figure 2 (con't)

Figure 2c

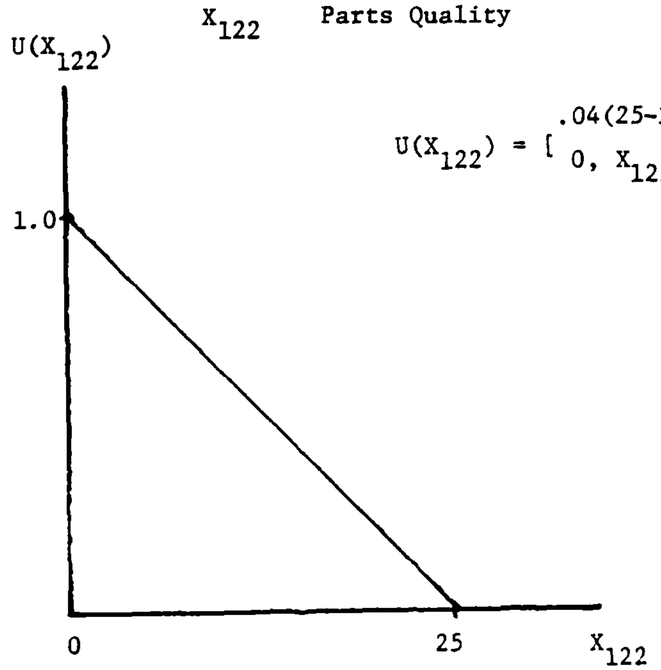
X_{121} Parts Timely



$$U(X_{121}) = \begin{cases} .0333(30-X_{121}), 0 \leq X_{121} \leq 30 \\ 0, X_{121} > 30 \end{cases}$$

Figure 2d

X_{122} Parts Quality



$$U(X_{122}) = \begin{cases} .04(25-X_{122}), 0 \leq X_{122} \leq 25 \\ 0, X_{122} >25 \end{cases}$$

Figure 2 (con't)

Figure 2e

X_{13} Floor Space

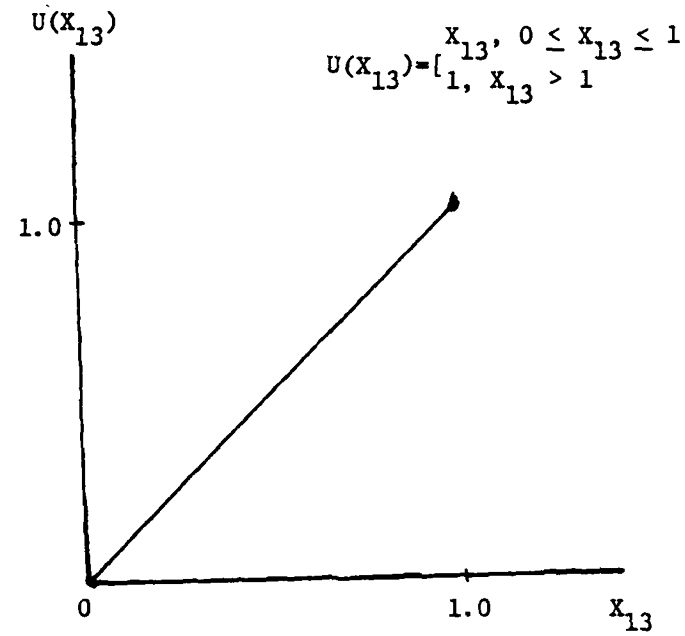


Figure 2f

X_{21} Safety

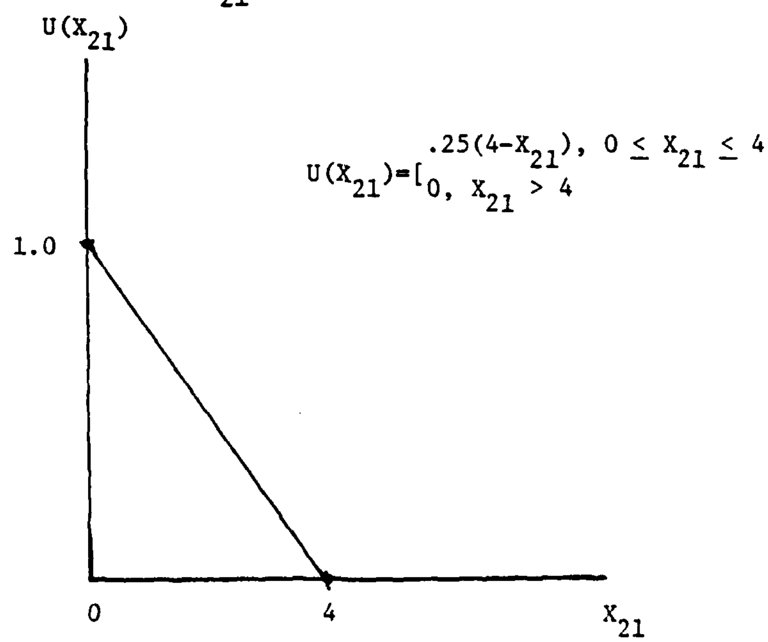


Figure 2 (con't)

Figure 2g

X_{221} Manning

$U(X_{221})$

$$U(X_{221}) = \begin{cases} 0, & X_{221} < .8 \\ 5(X_{221} - 0.8), & 0.8 \leq X_{221} \leq 1.0 \\ 1, & X_{221} > 1 \end{cases}$$

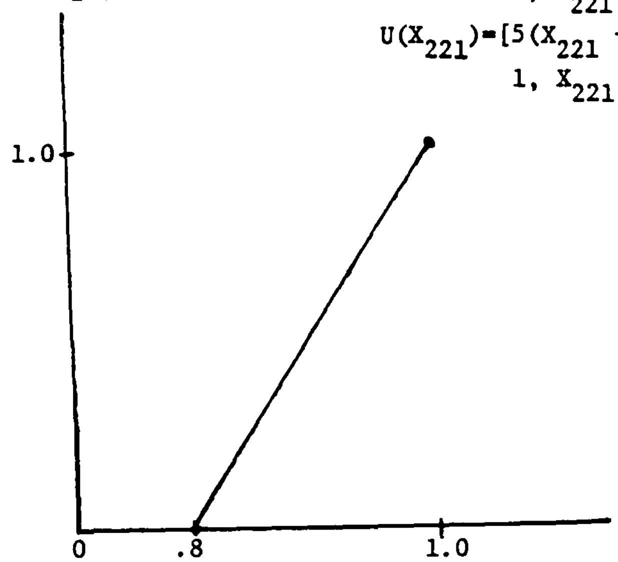


Figure 2h

X_{2221} Skill Level 7

$U(X_{2221})$

$$U(X_{2221}) = \begin{cases} 0, & X_{2221} < 24 \\ .0278(X_{2221}-24), & 24 \leq X_{2221} \leq 60 \\ 1, & X_{2221} > 60 \end{cases}$$

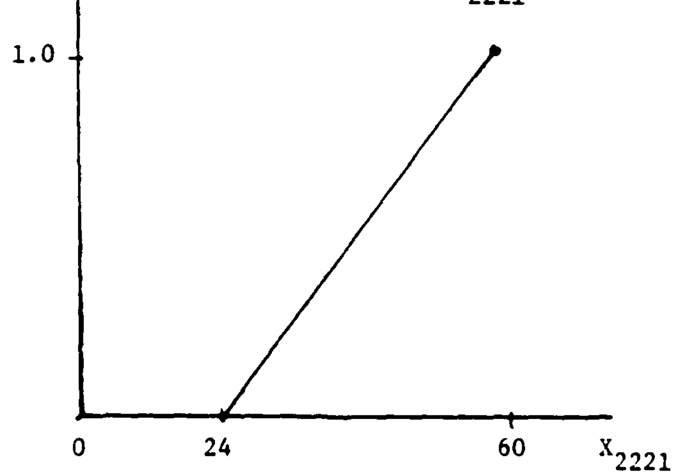


Figure 2 (con't)

Figure 2i

X_{2222} Skill Level 5

$$U(X_{2222}) = \begin{cases} 0, & X_{2222} < 12 \\ .0833(X_{2222}-12), & 12 \leq X_{2222} \leq 24 \\ 1, & X_{2222} \geq 24 \end{cases}$$

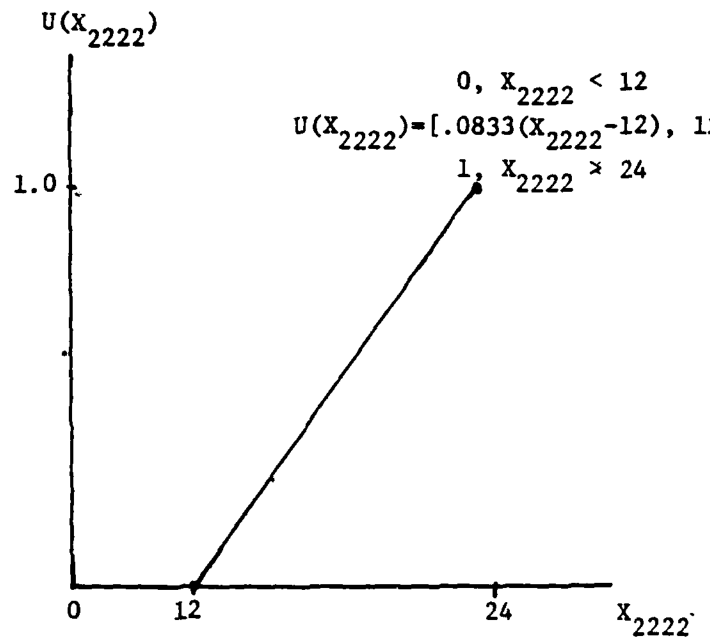


Figure 2j

X_{2223} Skill Level 3

$$U(X_{2223}) = \begin{cases} 0, & X_{2223} < 6 \\ .1667(X_{2223} - 6), & 6 \leq X_{2223} \leq 12 \\ 1, & X_{2223} > 12 \end{cases}$$

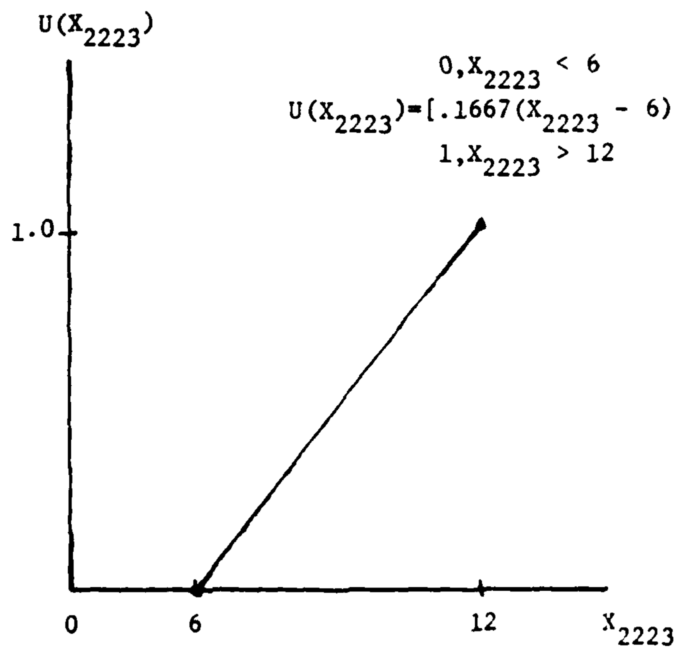
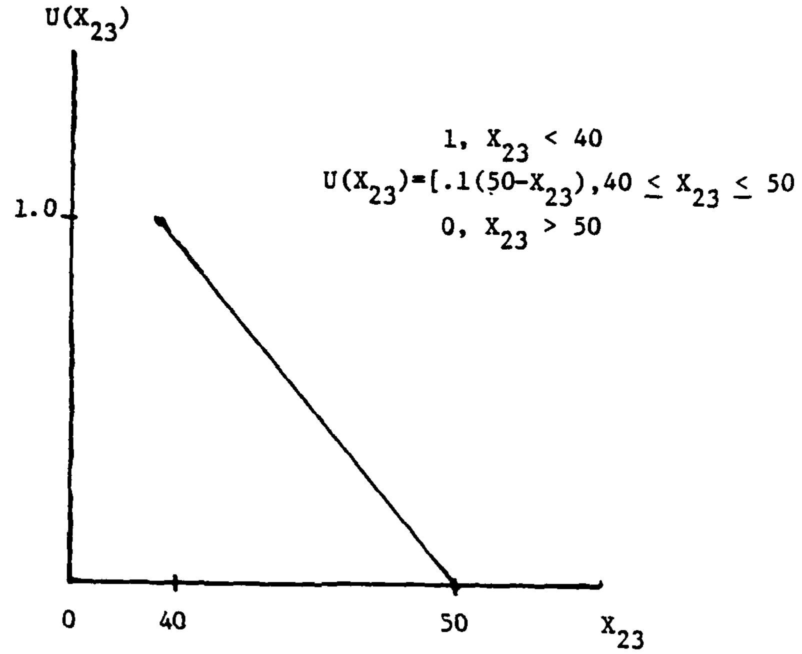


Figure 2 (con't)

Figure 2k

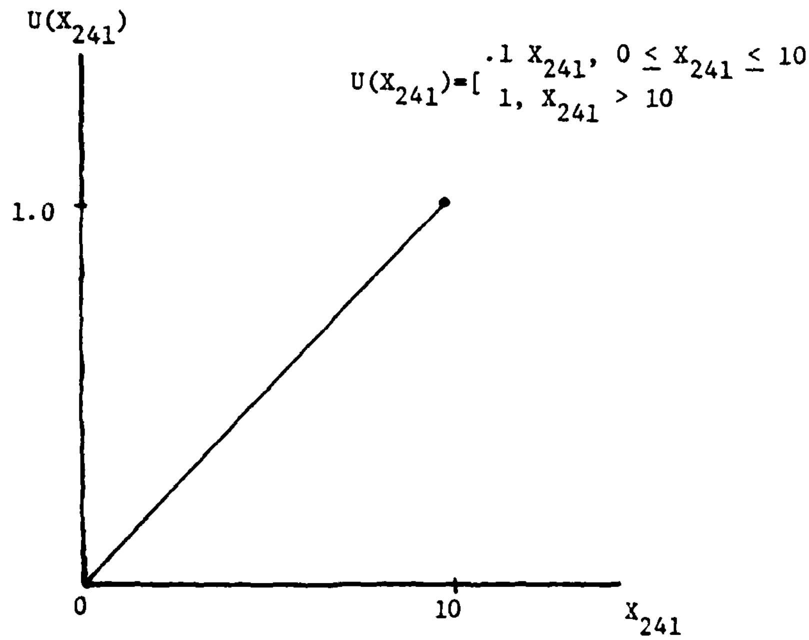
X_{23} Work Load



$$U(X_{23}) = \begin{cases} 1, & X_{23} < 40 \\ .1(50-X_{23}), & 40 \le X_{23} \le 50 \\ 0, & X_{23} > 50 \end{cases}$$

Figure 2l

X_{241} Correct/Timely Information



$$U(X_{241}) = \begin{cases} .1\,X_{241}, & 0 \le X_{241} \le 10 \\ 1, & X_{241} > 10 \end{cases}$$

Figure 2 (con't)

Figure 2m

X_{242} Information from Air Crew

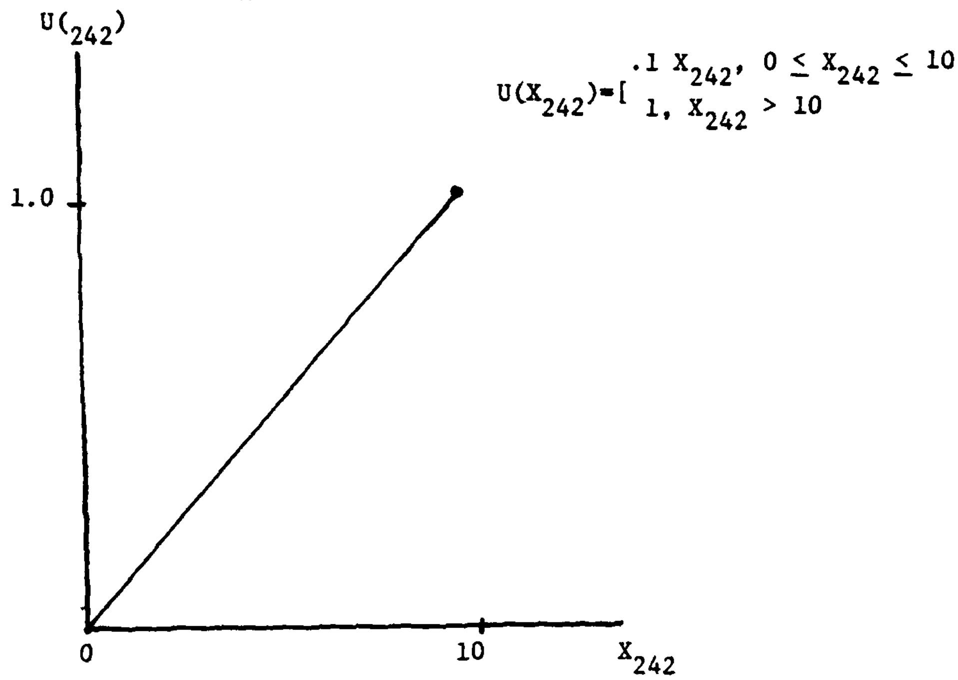


Figure 2n

X_3 Money Actual/Budget

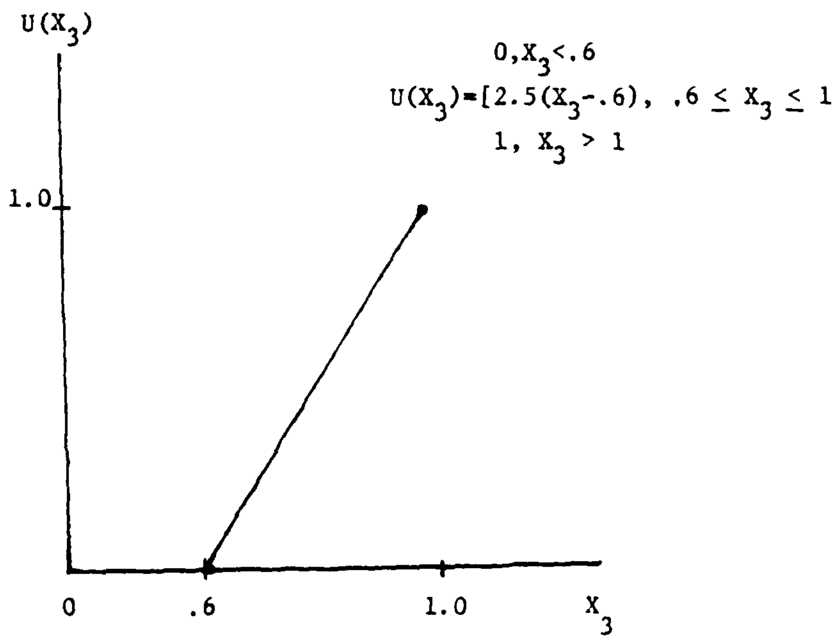
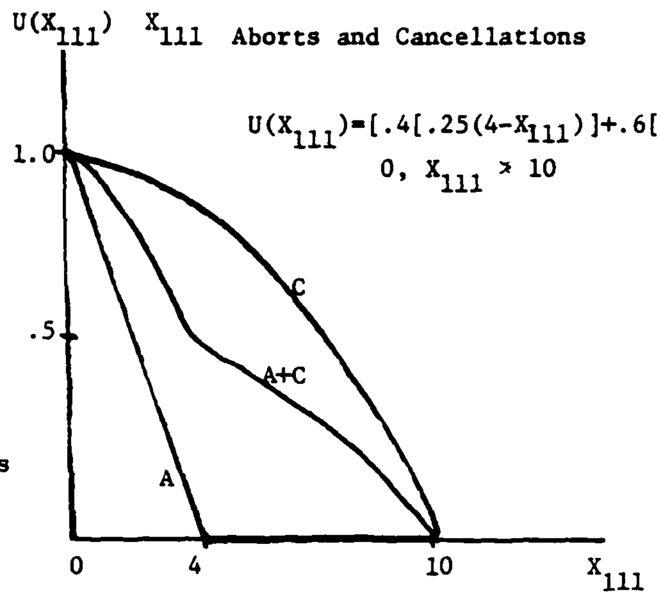


Figure 3

O.M.S. Attribute Utility Functions

Figure 3a

X_{111} Aborts and Cancellations



$$U(X_{111}) = [.4[.25(4-X_{111})] + .6[-.01\,X_{111}^{2} + 1],\ 0 \le X_{111} \le 10$$
$$0,\ X_{111} > 10$$

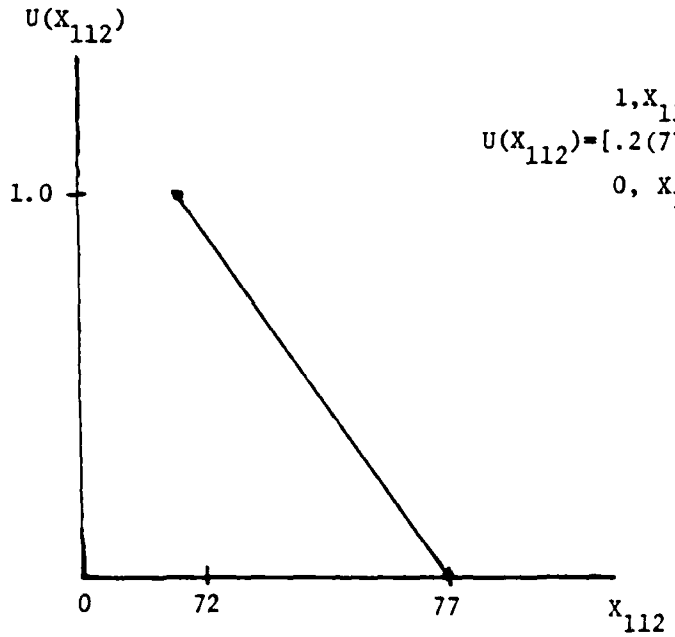
A = Aborts

C = Cancellations

A+C = .4 Aborts + .6 Cancellations

Figure 3b

X_{112} Sorties per Month



$$U(X_{112}) = \begin{cases} 1, & X_{112} < 72 \\ .2(77-X_{112}), & 72 \le X_{112} \le 77 \\ 0, & X_{112} > 77 \end{cases}$$

Figure 3 (con't)

Figure 3c

X_{121} Parts Timely

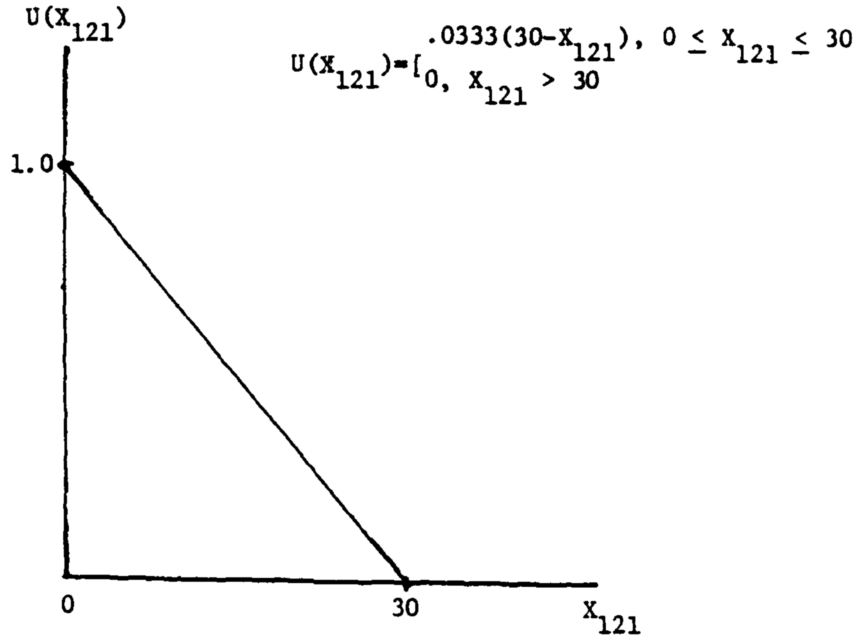


Figure 3d

X_{122} Parts Quality

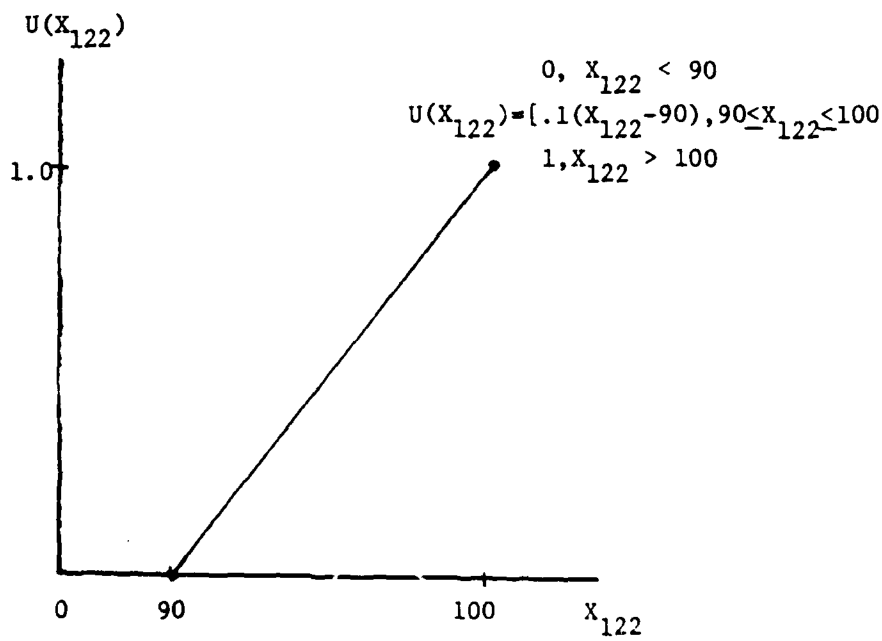


Figure 3 (con't)

Figure 3e

X_{131} Aircraft Parking

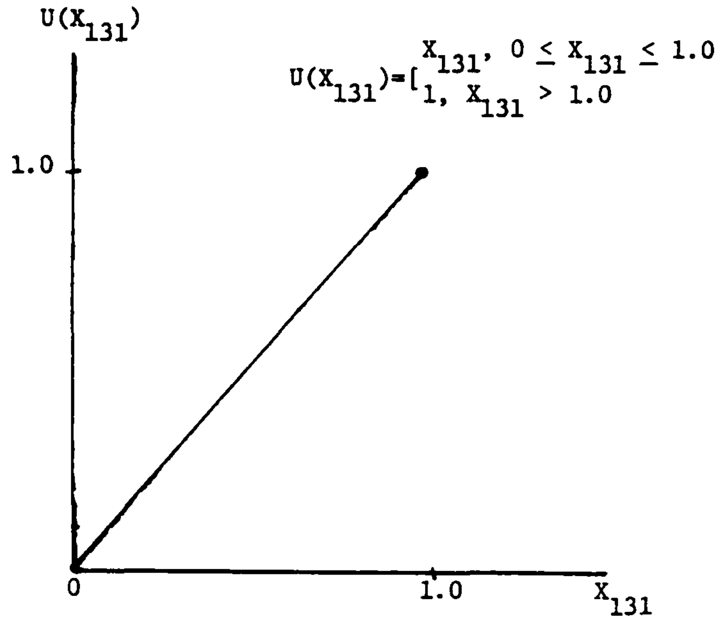


Figure 3f

X_{132} Inspection Facilities

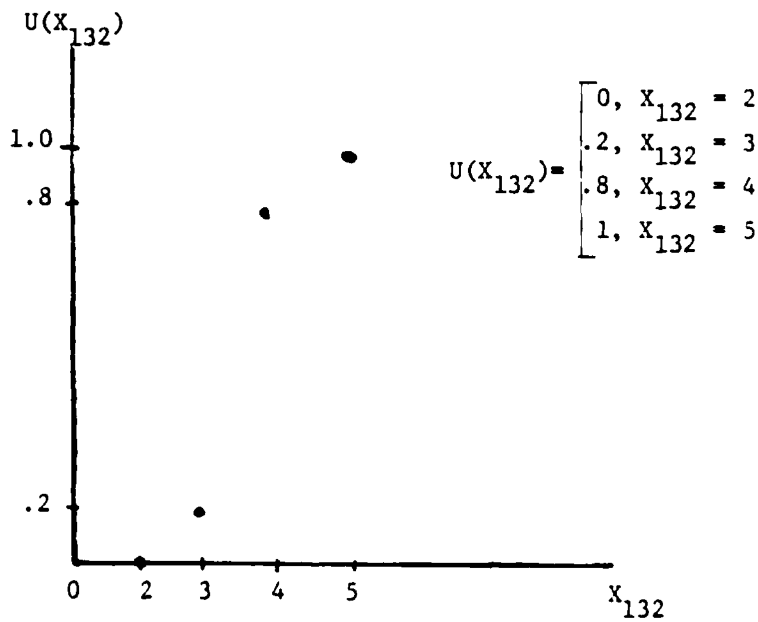
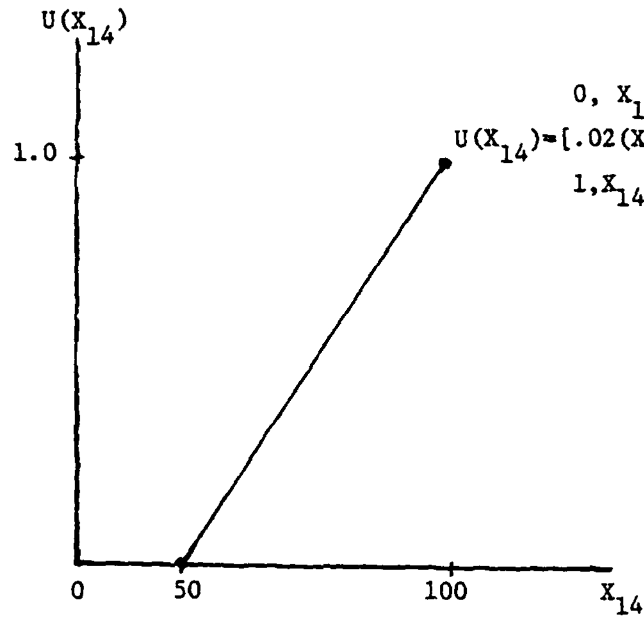


Figure 3 (con't)

Figure 3g

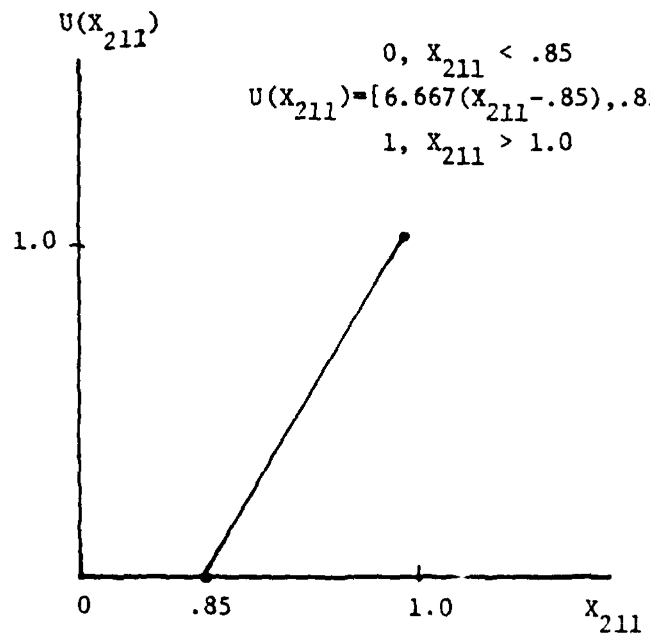
X_{14} Flight Line Communications



$$U(X_{14}) = \begin{cases} 0, & X_{14} < 50 \\ .02(X_{14}-50), & 50 \le X_{14} \le 100 \\ 1, & X_{14} > 100 \end{cases}$$

Figure 3h

X_{211} P.R.P.



$$U(X_{211}) = \begin{cases} 0, & X_{211} < .85 \\ 6.667(X_{211}-.85), & .85 \le X_{211} \le 1.0 \\ 1, & X_{211} > 1.0 \end{cases}$$

Figure 3 (con't)

Figure 3i

X_{212} Manning

$$U(X_{212}) = \begin{cases} 0, & X_{212} < .85 \\ 6.6667(X_{212} - .85), & .85 \le X_{212} \le 1.0 \\ 1, & X_{212} > 1.0 \end{cases}$$

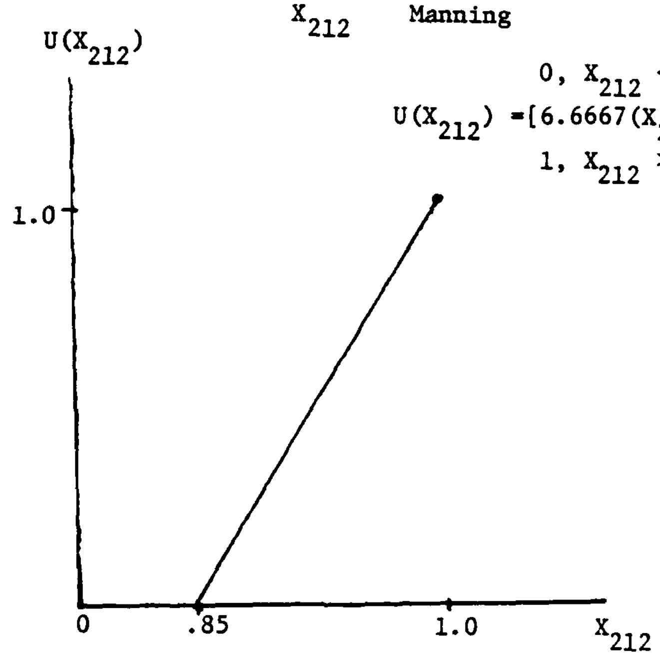


Figure 3j

X_{2131} Skill Level 7

$$U(X_{2131}) = \begin{cases} 0, & X_{2131} < 24 \\ 1/1296(X_{2131} - 24)^2, & 24 \le X_{2131} \le 60 \\ 1, & X_{2131} > 60 \end{cases}$$

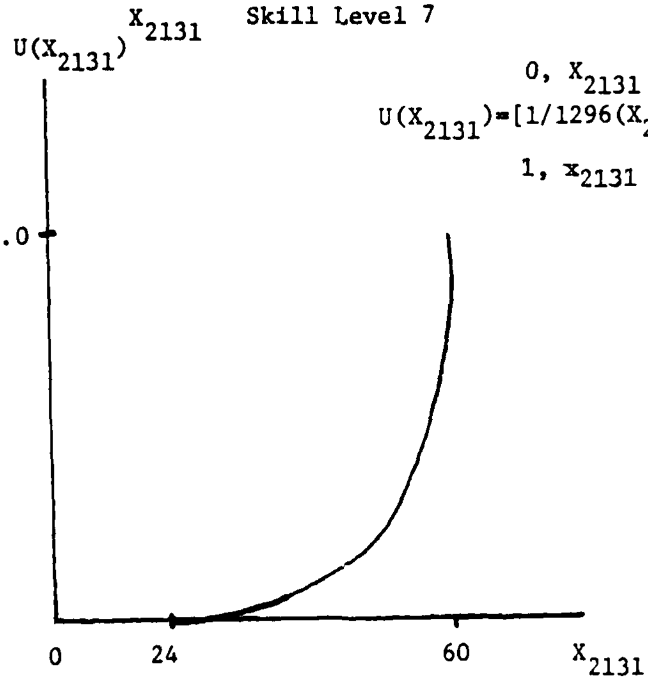


Figure 3 (con't)

Figure 3k

X_{2132} Skill Level 5

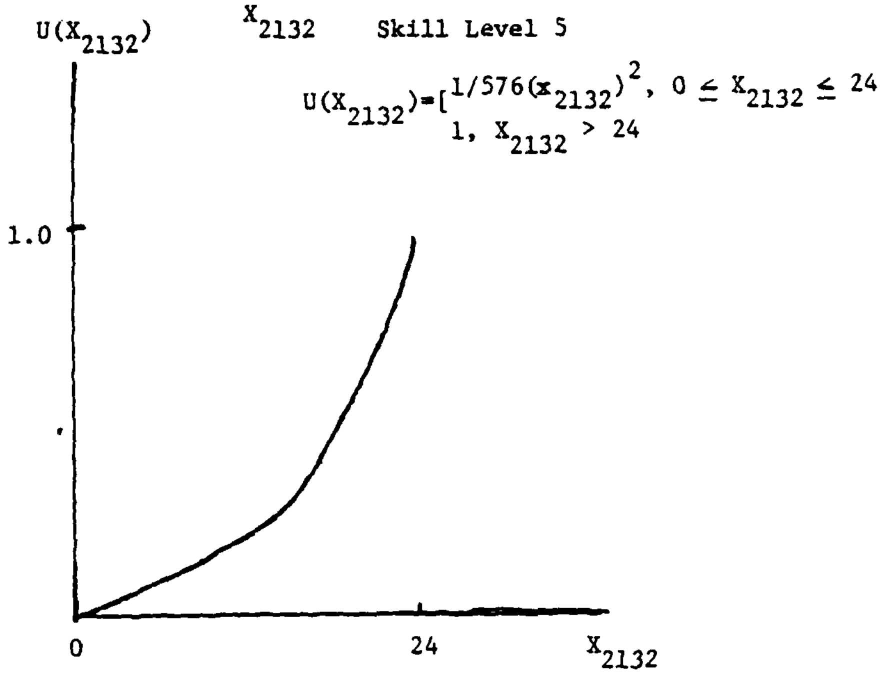


Figure 31

X_{221} Shift Hours per Week

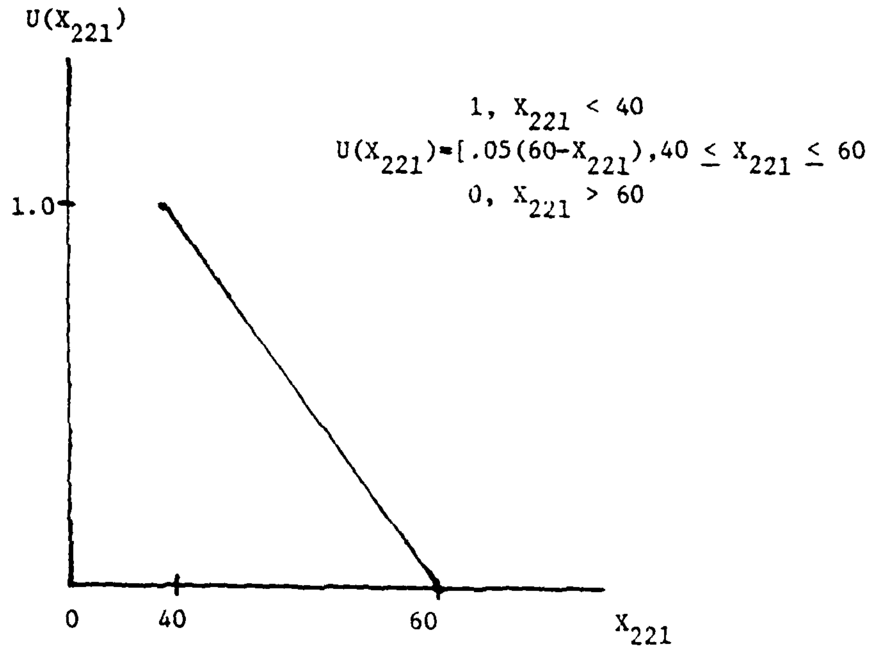


Figure 3 (con't)

Figure 3m

X_{222} Living Quarters

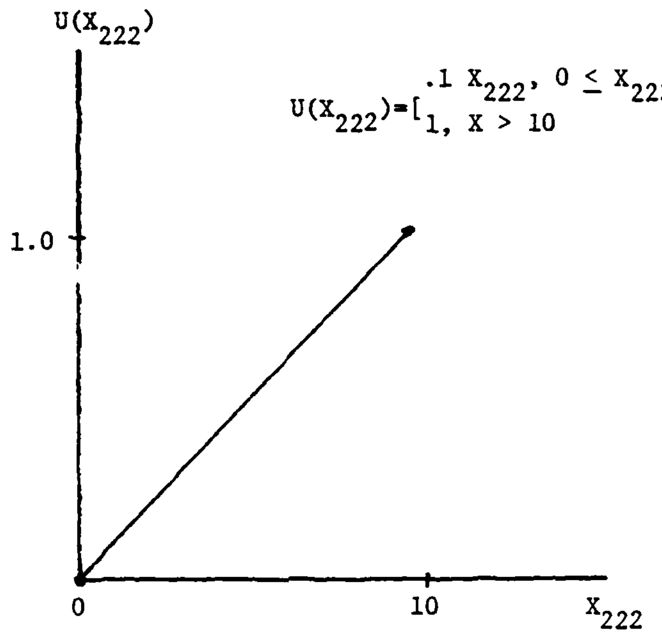


Figure 3n

X_{23} Squadron Communications

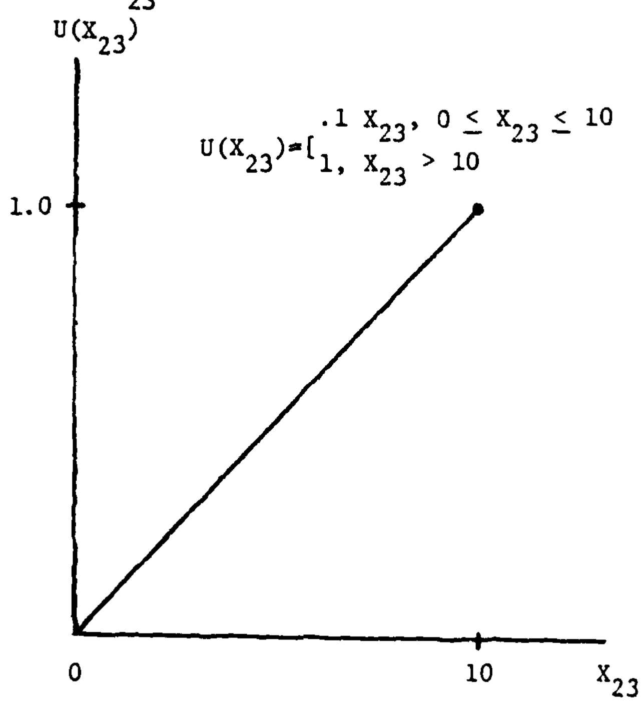


Figure 3 (con't)

Figure 3o

X_3 Money Funded/Budget Request

$$U(X_3)=\begin{cases} 0, & X_3 < .8 \\ 11.1111(X_3-.8)^2, & .8 \le X_3 \le 1.1 \\ 1, & X_3 > 1.1 \end{cases}$$

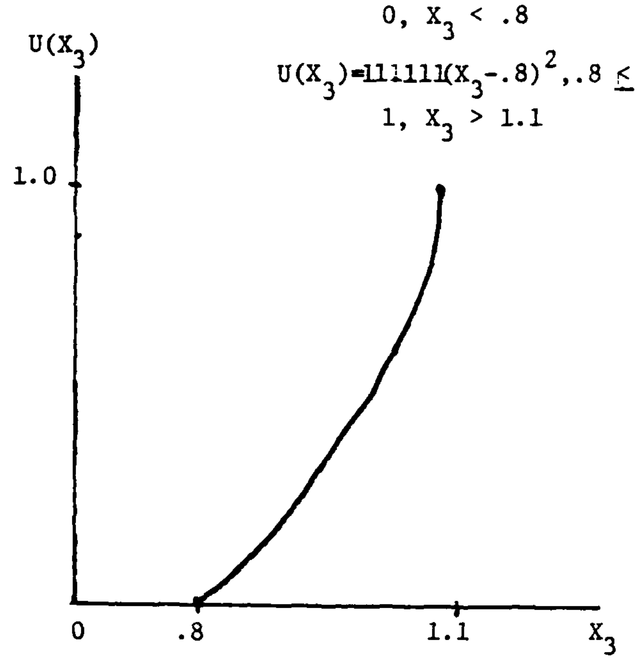


Figure 3p

X_4 Environment

$$U(X_4)=\begin{cases} .5(2-X_4), & 0 \le X_4 \le 2 \\ 0, & X_4 > 2 \end{cases}$$

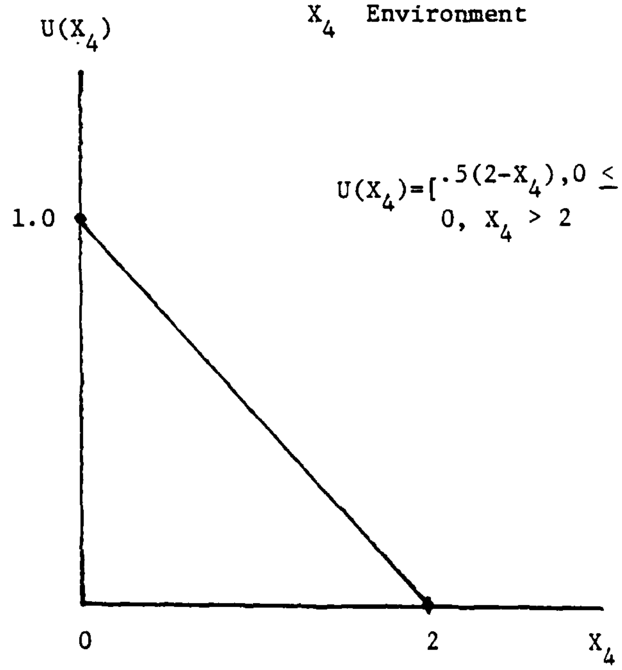


Figure 4

F.M.S. Attribute Utility Functions

Figure 4a

X_{111} % Aircraft - Red X

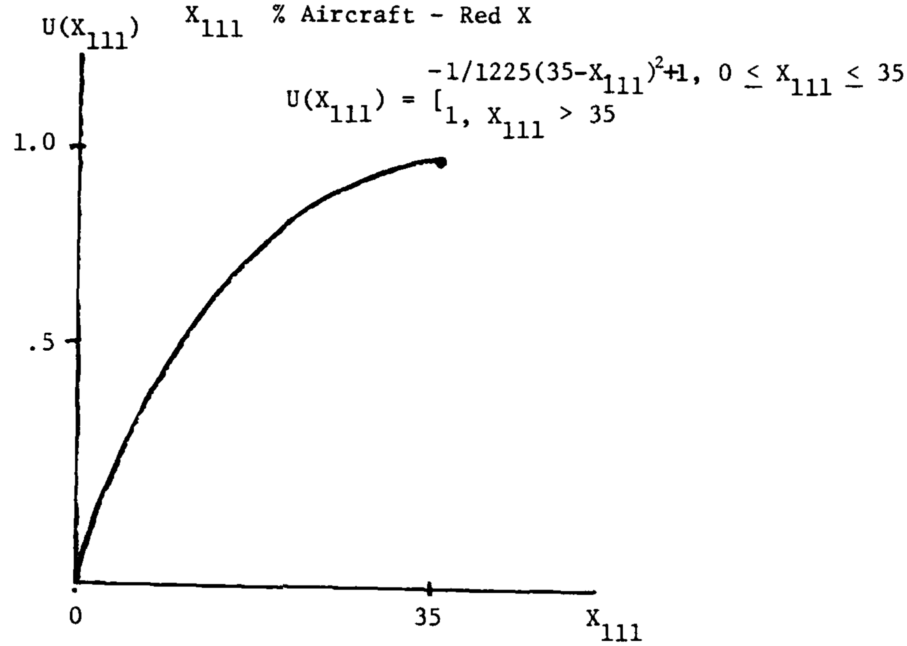


Figure 4b

X_{112} % Aircraft Diagonal

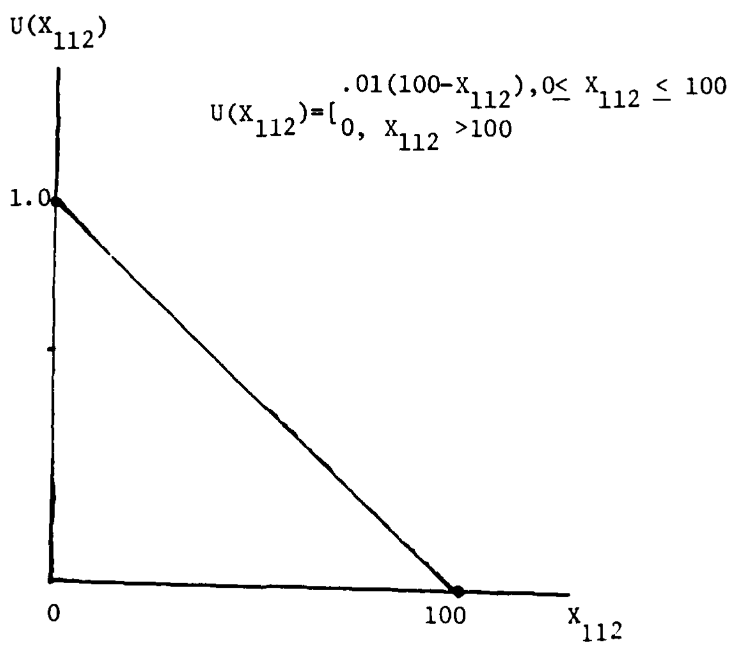


Figure 4 (con't)

Figure 4c

X_{121} % Ground Equip. Out

$$U(X_{121}) = \begin{cases} -1/900(30-X_{121})^2+1, & 0 \le X_{121} \le 30 \\ 1, & X_{121} > 30 \end{cases}$$

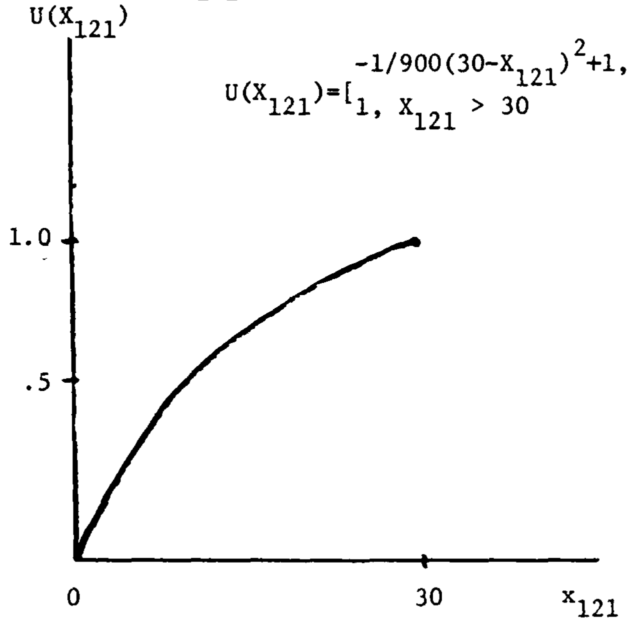


Figure 4d

X_{122} % Test Equip. Functioning

$$U(X_{122}) = \begin{cases} 0, & X_{122} < 90 \\ .1(X_{122}-90), & 90 \le X_{122} \le 100 \\ 1, & X > 100 \end{cases}$$

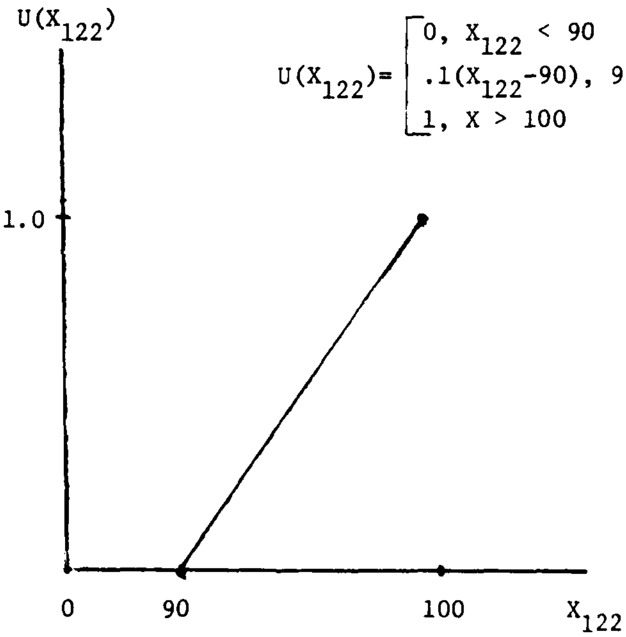
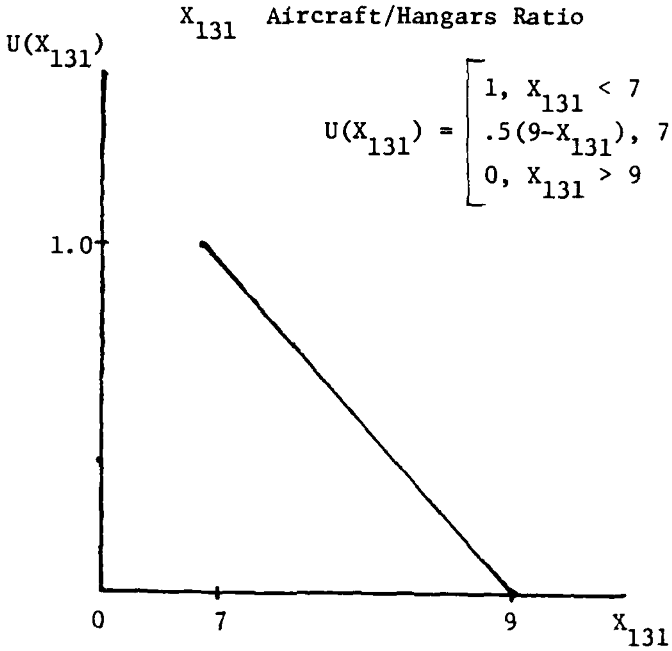


Figure 4 (con't)

Figure 4e

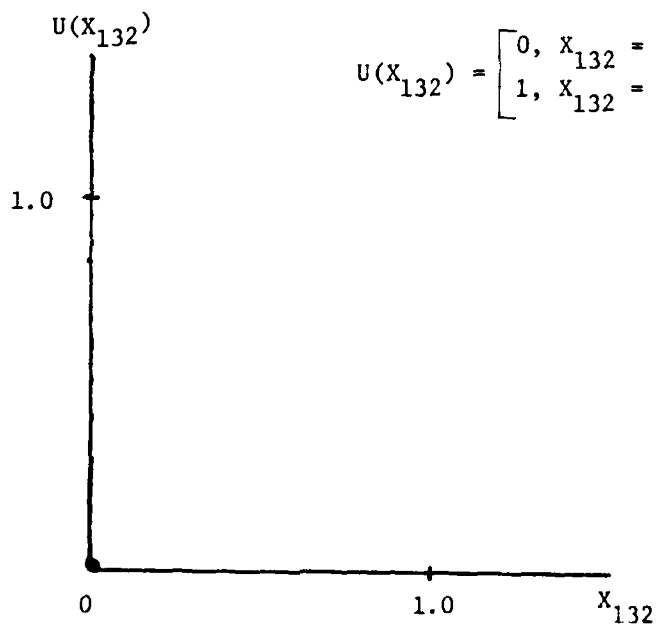
X_{131} Aircraft/Hangars Ratio



$$U(X_{131}) = \begin{cases} 1, & X_{131} < 7 \\ .5(9-X_{131}), & 7 \leq X_{131} \leq 9 \\ 0, & X_{131} > 9 \end{cases}$$

Figure 4f

X_{132} Test Cells



$$U(X_{132}) = \begin{cases} 0, & X_{132} = 0 \\ 1, & X_{132} = 1 \end{cases}$$

Figure 4 (con't)

Figure 4g

X_{133} Corrosion Facilities

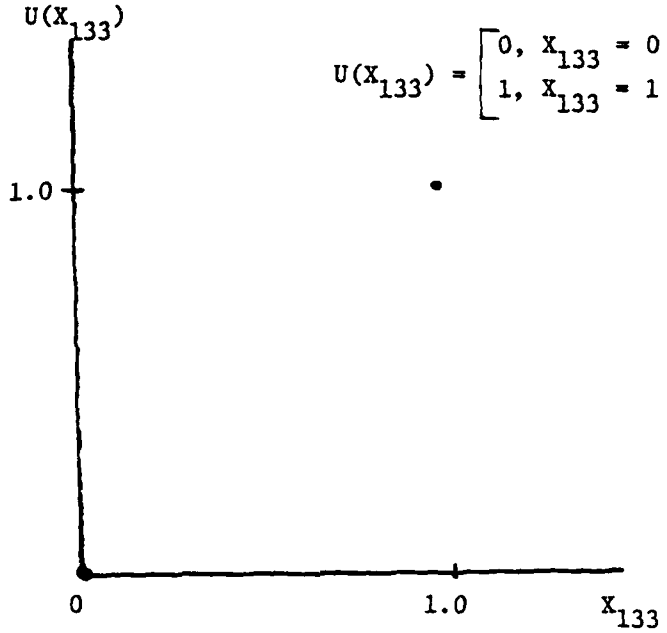


Figure 4h

X_{211} Manning

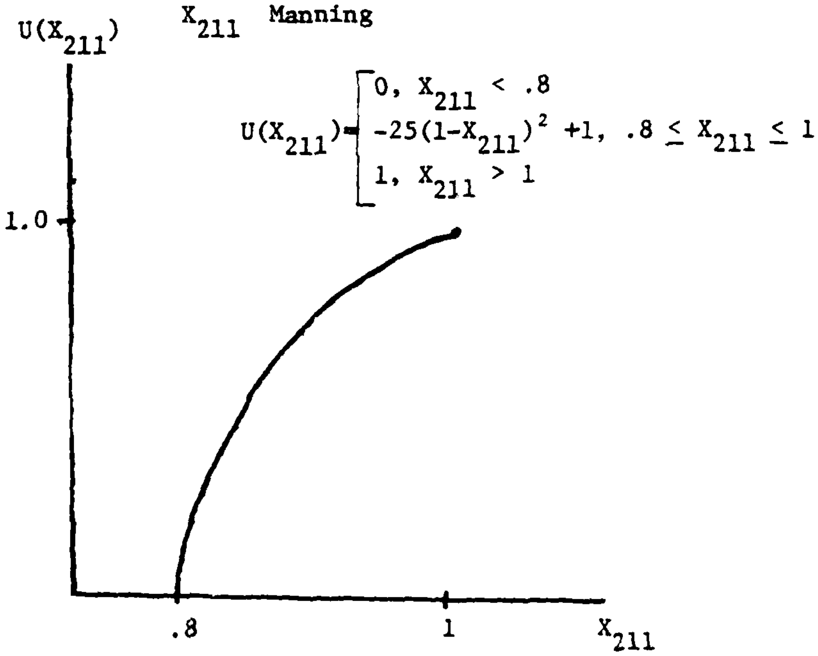


Figure 4 (con't)

Figure 4i

X_{212} Training

$$U(X_{212}) = \begin{cases} 1 - X_{212}, & X_{212} \geq 0, \quad X_{212} \leq 1.0 \\ 0, & X_{212} > 1.0 \end{cases}$$

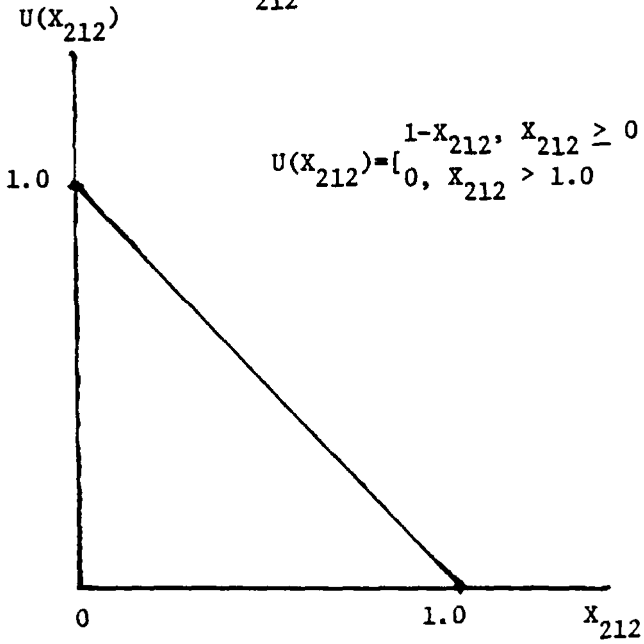


Figure 4j

X_{2131} Skill Level 7

$$U(X_{2131}) = \begin{cases} 0, & X_{2131} < 12 \\ .00077(X_{2131} - 12)^2, & 12 \leq X_{2131} \leq 48 \\ 1, & X_{2131} > 48 \end{cases}$$

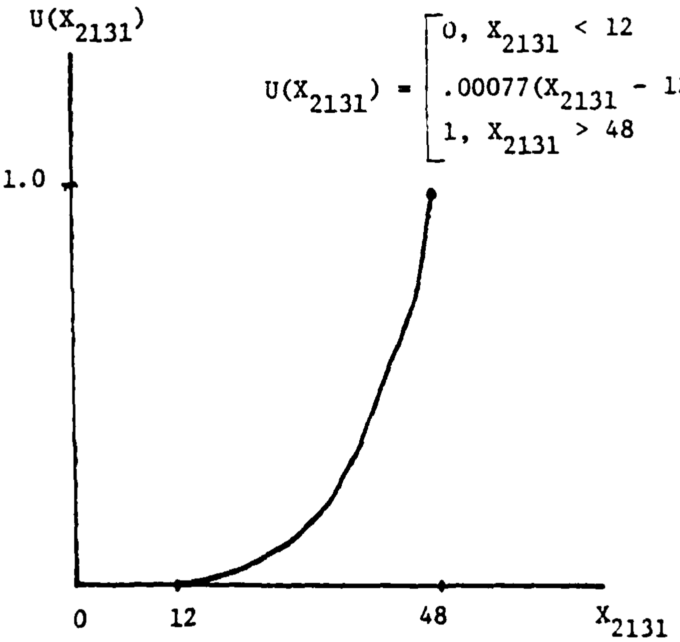


Figure 4 (con't)

Figure 4k

X_{2132} Skill Level 5

$$U(X_{2132}) = \begin{cases} 0, & X_{2132} < 12 \\ .0069(X_{2132}-12)^2, & 12 \leq X_{2132} \leq 24 \\ 1, & X_{2132} > 24 \end{cases}$$

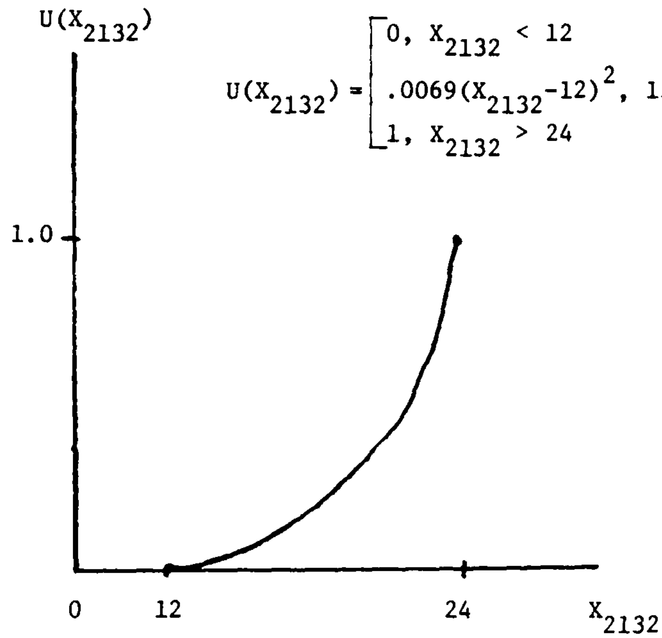


Figure 41

X_{2133} Skill Level 3

$$U(X_{2133}) = \begin{cases} .0069(X_{2133})^2, & 0 \leq X_{2133} \leq 12 \\ 1, & X_{2133} > 12 \end{cases}$$

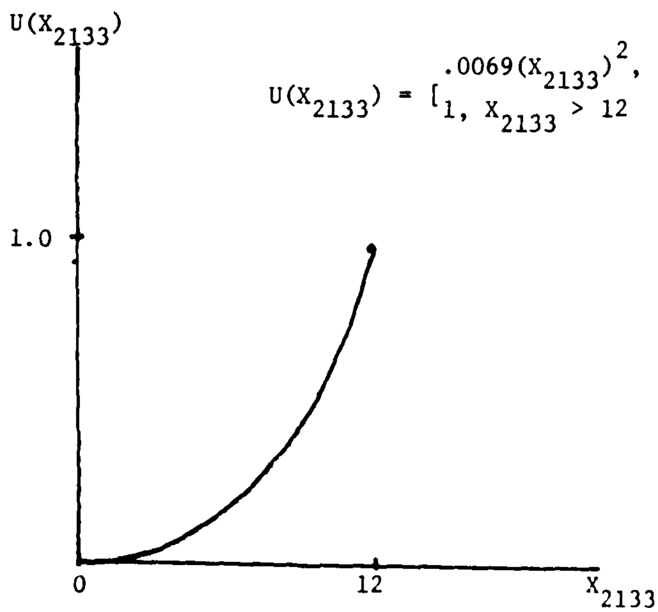
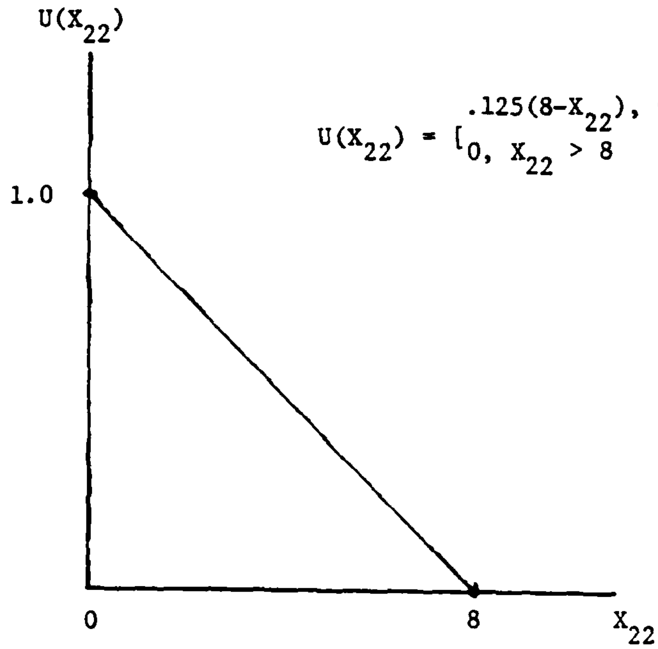


Figure 4 (con't)

Figure 4m

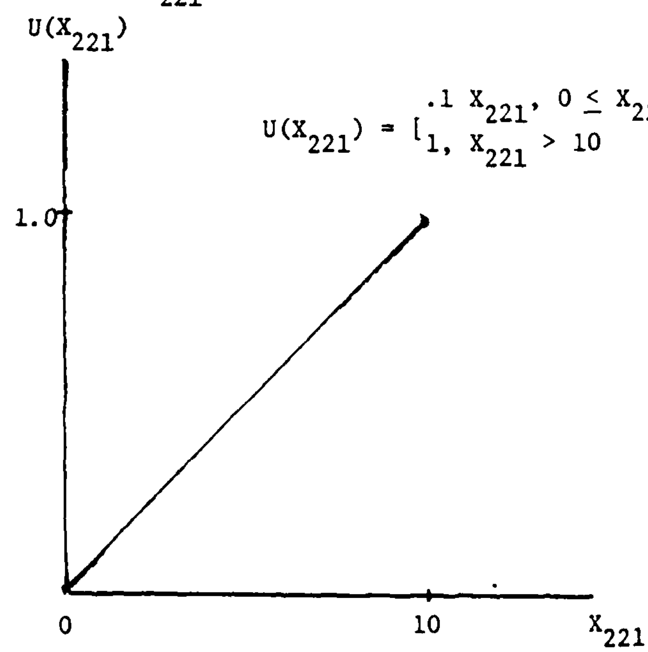
X_{22} Squadron Morale



$$U(X_{22}) = \begin{cases} .125(8-X_{22}), & 0 \le X_{22} \le 8 \\ 0, & X_{22} > 8 \end{cases}$$

Figure 4n

X_{221} Working Conditions



$$U(X_{221}) = \begin{cases} .1\, X_{221}, & 0 \le X_{221} \le 10 \\ 1, & X_{221} > 10 \end{cases}$$

Figure 4 (con't)

Figure 4o

X_{222} Living Conditions

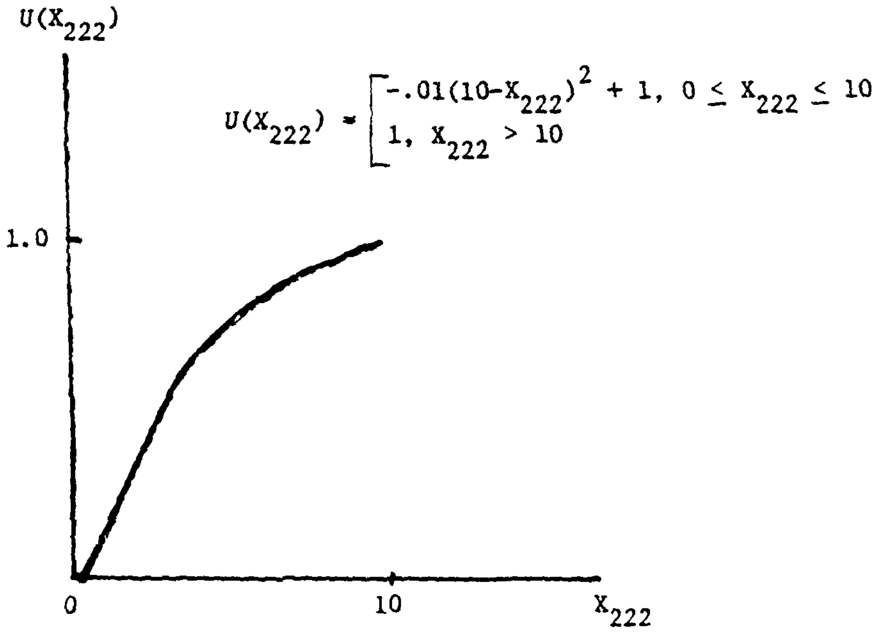


Figure 4p

X_{23} Safety

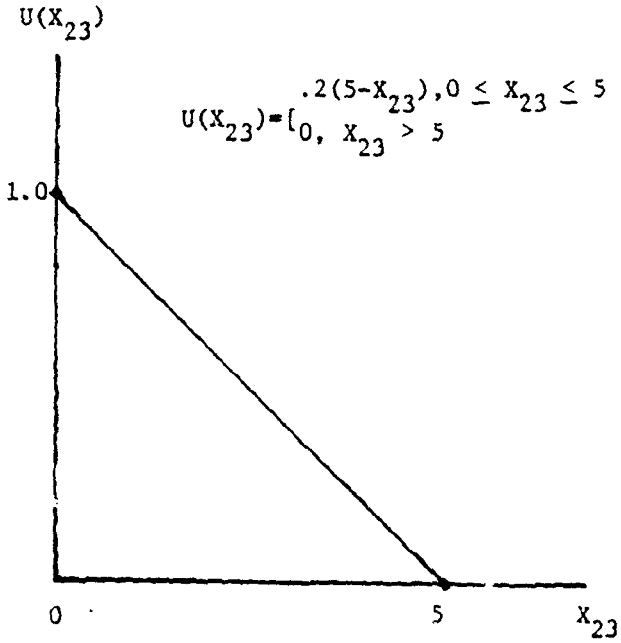


Figure 4 (con't)

Figure 4q

X_{24} Supervision

$$U(X_{24}) = \begin{cases} -.1(10-X_{24})^2 + 1, & 0 \leq X_{24} \leq 10 \\ 1, & X_{24} > 10 \end{cases}$$

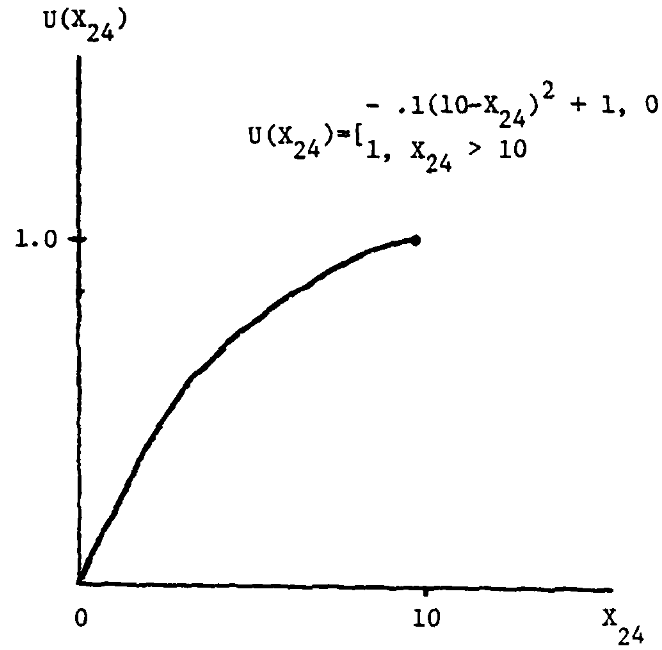


Figure 4r

X_3 Money

$$U(X_3) = \begin{cases} 0, & X_3 < 90 \\ -.0025(110-X_3)^2+1, & 90 \leq X_3 \leq 110 \\ 1, & X_3 > 110 \end{cases}$$

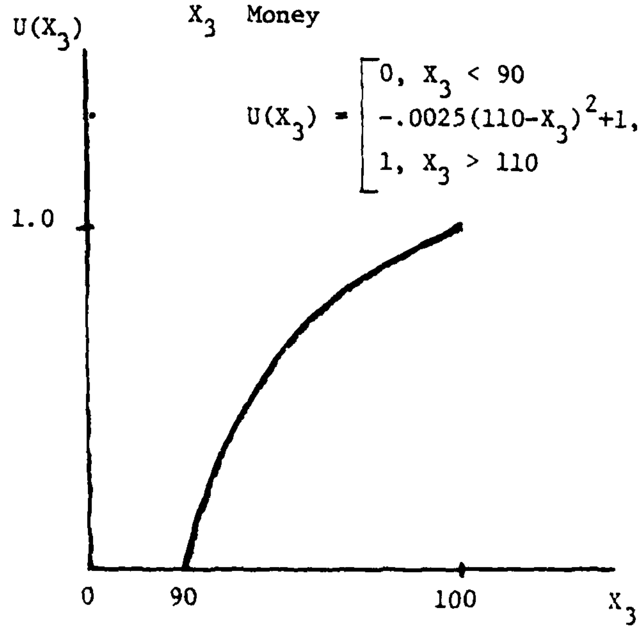
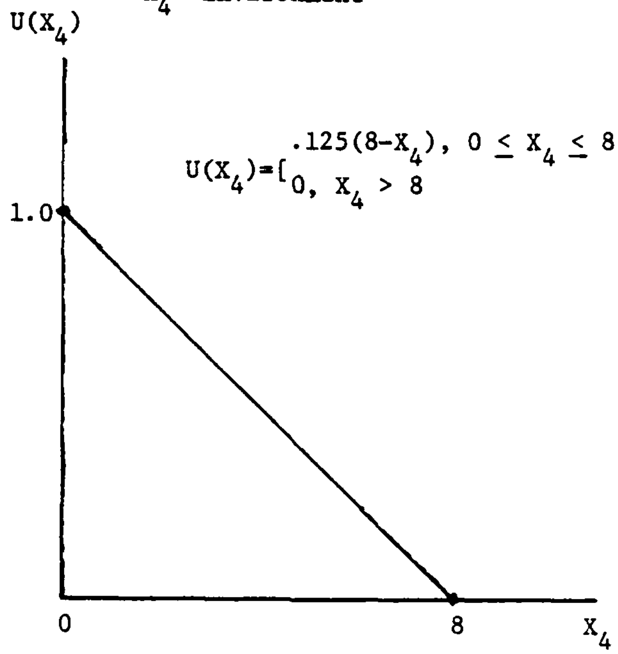


Figure 4 (con't)

Figure 4s

X_4 Environment



APPENDIX B

SAMPLE INTERVIEW FOR
ATTRIBUTE WEIGHTING

Analysts (A): Now we'd like to ask you some questions which force you to make some choices.

A: Let's say you have two choices. Choice number one is to command a maintenance squadron which has 0% backlog of equipment to be repaired (attribute number 1 for A.M.S.). There's a big catch to this choice however. Every other attribute is at its least desirable level.

Choice number two is a gamble: A squadron with every attribute at its most desirable level or each attribute at its least desirable level. There's a fifty-fifty chance of winding up with either case.

Squadron Commander (SC): In choice number one, 0% backlog is all I get?

A: Right, but you get that for sure while there's a 50% chance in choice number 2 that you don't even get that. Of course there's also a 50% chance that you'll get everything- every attribute at its most desirable level.

SC: Well, if all I get from choice number one is 0% backlog, then I would just as soon take my chances with choice two.

A: Fine. What if we change choice two so that there's only a 30% chance of getting every attribute at its most desirable level and 70% chance of getting every attribute at its least desirable level. Now which choice would you make?

SC: That's a little tougher, but I think I would still take my chances with choice number two. Just having 0% backlog doesn't mean that much to me.

A: O.K., let's do it again. What if there was only a 20% chance of getting every attribute at its most desirable level in choice number two?

SC: A 20% chance is almost a long shot. I guess I'd take choice one which gives me something for certain versus an 80% chance of getting nothing.

A: What if the probability of obtaining all attributes at their most desirable level was 25%?

SC: I just don't know. I guess either one.

- -

The squadron commander is indifferent between the two choices at a probability level of 0.25. Thus the weight for this attribute is 0.25.

APPENDIX C

DECISIONS EFFECTING

PRODUCTIVITY

AD-A092 250 AUBURN UNIV AL DEPT OF INDUSTRIAL ENGINEERING F/G 5/1
MAINTENANCE PRODUCTIVITY.(U)
SEP 80 C R WHITE AFOSR-79-0016
UNCLASSIFIED AFOSR-TR-80-1175 NL

2 of 2

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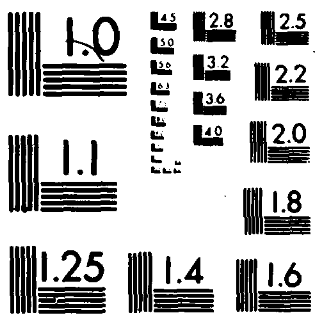


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963 A

Decision Set of DCM

Decision	Description
1	On an exception basis, when confronted with an urgent problem, DCM can recommend maintenance priorities to Wing Commander in order to maximize use of expertise in maintenance. Example: On Friday, DCM may recommend that (and convince) Wing Commander to forego maintenance efforts on a Friday flight that is "late" in order to have "Monday's aircraft" ready.
2	Straighten out paper work requirements. May use rank and authority to solve subordinates problems in completing documentation of Sortie proficiency reports, for example.
3	When over budget for quarter in some area, can shift funds from one group to another. Note: Annual budget is 3.5-4 MM$.
4	MSEP scores, evaluated annually by SAC can influence MSEP scores by requesting Q.C. personnel to be highly critical during inspections. Larsen: "Our inspectors are tougher than SAC"
5	Recommend training for repeat write-up offenders. However, squadrons make training decisions.
6	Can request manpower, but actually can do little to increase manpower. However, can shift personnel from one squadron to another temporarily.
7	OER's and APR's. OER on each of 4 squadron commanders and 1 maintenance control officer. APR on Technical Advisor. APR requires 5 endorsements, OER requires 2 endorsements. Part of this decision is the endorsement level. For good performers, may pass on to higher authority for endorsements to help subject's career.
8	Authorization for cannabilization can come from Maint. Control Officer, but DCM is closely involved with cannabilization decisions.
9	Leaves and passes for staff and key people in squadrons. Places limit on number of key people that can be on leave at any one time.

DCM Decision Set

Decision Number	Decision
1	Recommend maintenance priorities
2	Resolve documentation problems
3	Shift funds
4	Request more critical QC inspection
5	Recommend training
6	Request manpower
7	Endorsement level of OER and APR
8	Authorize cannabilization
9	Grant leaves and passes

Attribute/Decision Relationship

1	Direct impact on X_{112}, X_{111}
	Indirect impact on X_{222}, X_{121}
2	Direct impact on X_{32}, X_{21}, X_{23}
3	Direct impact on X_{31}, X_{32}, X_{121}
4	Direct impact on X_{21}
5	Direct impact on X_{21}
	Indirect impact on X_{23}
6	Direct impact on X_{21}, X_{111}, X_{23}
7	Direct impact on X_{221}
8	Direct impact on X_{121}, X_{122}
9	Direct impact X_{221}

A.M.S. Decision Set

Decision Number	Decision
1	Expenditures on supplies and equipment
2	Duty hours and shifts (with some limitations)
3	Non-judicial punishment
4	PAQ,BAS - quarters, rations
5	PCS assignment and TDY
6	Promotion recommendations
7	Unfavorable information file
8	OER, APR
9	Level of maintenance to be performed
10	Within squadron assignments
11	Timing of equipment purchases
12	Percentage of time devoted to training

Attribute/Decision Relationships

Decision Number	has some impact on	Attribute Number
1		X_{111}, X_{121}, X_{122}, X_{112}, X_{23}, X_{21}, X_3
2		X_{111}, X_{241}, X_{242}, X_{23}, X_{21}
3		X_{23}, X_{21}
4		X_{23}, X_{21}
5		X_{221}, X_{2221}, X_{2222}, X_{2223}, X_{23}, X_{21}
6		X_{221}, X_{2221}, X_{2222}, X_{2223}, X_{23}
7		X_{23}, X_{21}
8		X_{221}, X_{2221}, X_{2222}, X_{2223}, X_{23}, X_{21}
9		X_{111}, X_{121}, X_{122}, X_{23}, X_{21}
10		X_{221}, X_{23}
11		X_{111}, X_{112}, X_{13}, X_{2221}, X_{2222}, X_{2223}, X_{23}
12		X_{111}, X_{241}, X_{242}, X_{221}, X_{2221}, X_{2222}, X_{2223}, X_{23}, X_{21}

F.M.S. Decision Set

Decision Number	Decision
1	Leaves and passes
2	Promotions and demotions
3	Training
4	Cross-training recommendations
5	Recommendations for awards and decorations
6	APR, OER
7	Position assignments
8	Duty hours and shifts
9	Maintenance and cleaning emphasis

Attribute/Decision Relationships

Decision Number	Attribute Number
1	Has impact on X_{22}
2	Has impact on X_{21}, X_{22}
3	Has impact on X_{2131}, X_{2132}, X_{2133} perhaps long term effect on X_{21}
4	Direct impact on X_{212} has impact on X_{21}, X_{2131}, X_{2132}, X_{2133} some impact on X_{22}
5	Direct impact on X_{22}
6	Direct impact on X_{22} has impact on X_{24}
7	Direct impact X_{111}, X_{112}, very little impact X_{221} has some impact on X_{121}, X_{23}, X_{24}, X_{22}
8	Direct impact on X_{111}, X_{112}, X_{121}, If over 8 hrs. X_{23},X_{221},X_{22}
9	Direct impact on X_{111}, X_{112}, X_{121}, X_{23}, X_{24}, X_4, X_{22}, X_{221} has some impact on X_{122}

O.M.S. - Lt. Col. Patterson - Decision Set

Decision Number	Description
1	Assignment of key personnel - promote to branch chief, down grade, etc. Punishment for disciplinary action (Article 15, denote).
2	Eliminate personnel from service recommendation (3912)
3	Expenditure of funds: equipment vs. aircraft parts
4	Assignment for mobility and/or Emergency War Order (EWO) commitment
5	Who is qualified for PRP.

O.M.S. Decision Set

Decision Number	Decision
1	Assignment of key personnel
2	Eliminate personnel from service recommendation
3	Expenditure of funds
4	Assignment for mobility and Emergency War Order Commitment
5	P.R.P. Qualification

Attribute/Decision Relationships

Decision Number	Attribute Number
1	Direct impact on X_{211} Indirect impact on X_{111}
2	Direct impact on X_{111}, X_{112}, X_{212}, X_{2131}, X_{211}, X_{222}, X_{2132}
3	Direct impact on X_{111}, X_{121}, X_{14}, X_{3}
4	Direct impact on X_{111}, X_{121}, X_{14}, X_{112}, X_{212}, X_{2131}, X_{211}, X_{222}, X_{221}, X_{2132}
5	Direct impact on X_{111}, X_{112}, X_{212}, X_{2131}, X_{211}, X_{2132}

APPENDIX D

Other Models

Colonel Lindsay - Commander of Armament System

Mr. Thoren - Chief of the Computer Sciences Directorate

Eglin AFB

Florida

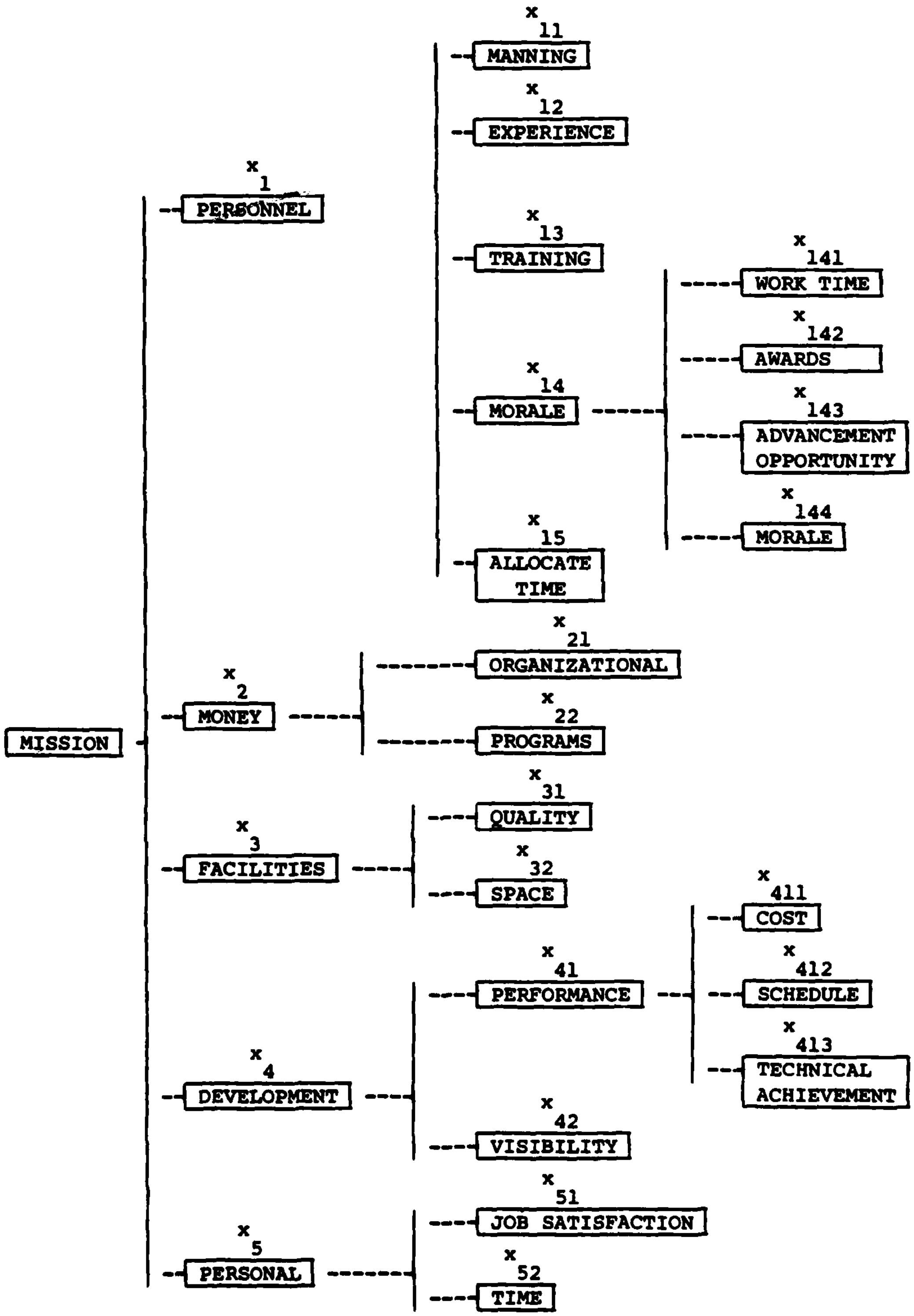
THE ARMAMENT SYSTEMS (SD) MODEL

This study was conducted with the Deputy of Armament Systems (SD), Colonel James Lindsay. His background proved to be ideal for the development of a utility model. He has bachelor of science degrees in Chemistry and Mechanical Engineering and later received a master's degree in Business from Auburn University. Colonel Lindsay received his commission in 1952 and flew fighters from 1952 to 1961 and again in 1966-67 in Vietnam. He went into systems work in 1963 and has continued in systems assignments to the present except for the time in Vietnam. In 1975 he became Deputy of SD.

The overall mission of SD is the management of development and acquisition programs related to conventional weapons systems. Colonel Lindsay sees five major factors as important to accomplishment of the SD mission. These are personnel, money, facilities, development, and personal. The personal factor proved to be almost insignificant in comparison to the other major areas. The hierarchy of factors and attributes are shown in Figure 2. The attributes are the measured or estimated variables which determine the overall model.

FIGURE 2

COLONEL LINDSAY



Attributes and Model for Colonel Lindsay

The analysts encouraged the development of a minimally complete and "independent" set of attributes throughout the process. Questions concerning the meaning of attributes and the nature of scales upon which projects could be rated for each attribute were posed. Elementary examples of preferential and utility independence were given as guidance. Despite the encouragement given by the analysts for selecting "independent" attributes, the decision maker was told to always hold firm to any selection for which he felt strongly committed. The final attribute list as presented herein has truly been evolutionary throughout the study and has been of some concern in every session between the decision maker and the analysts.

It was found to be necessary to use hierarchical approaches (25) in going from broad objectives to specific attributes.

Attribute Definition

The overall mission of SD is the management of development and acquisition programs. The decisions that Colonel Lindsay considers important in the accomplishment of the SD mission are given in Table 1. The major factors, personnel, money, facilities, development, and personal, are broad factors which do not lend themselves to measurement, and must be broken down into attributes which are measurable on either objective or subjective scales.

TABLE 1

COLONEL LINDSAY

DECISIONS

D_1	Organization
D_{11}	Merge SPOs
D_{12}	Reduce Staff
D_2	Facility Requirements
D_{24}	Space
D_{22}	Equipment
D_3	Project
D_{31}	Type of Contract (Influence)
D_{32}	Turn Down
D_4	Personnel
D_{41}	Approve Position Description
D_{42}	Request People or Authorization
D_{43}	Administer Punitive Actions
D_{44}	Select Personnel for Special Projects
D_{441}	Placement
D_{442}	Strategy to Develop
D_{45}	Administer Awards

Under the broad factor personnel, the decision maker identified manning, experience, training, morale, and time allocation as measurable attributes.

Manning is defined as the manyears required to accomplish the project workload. The measure chosen for this attribute was manyears short on a scale from 400 to zero.

Experience is the amount of work performed in the past on similar jobs. The decision-maker estimates the overall experience levels on a scale of zero to three with zero being not adequate, one is adequate, two is very good, and three is ideal.

Training is required to prepare personnel to use new technology and to accept promotion into more responsible positions. The percent of total time spent on training is a measure ranging from none to the ideal of five percent.

Morale is an attribute which may be broken down into subattributes, work time, awards, upward mobility, and morale. Work time is ideal if the employee works forty hours per week and any hours over fifty is unacceptable. The percent of people getting awards annually should ideally be about five percent. The advancement opportunity refers to the rate at which employees are promoted to better paying and more responsible positions. The upward mobility subattribute is measured on a subjective scale from zero to five. A zero implies no

promotion and a five means those persons seeking and deserving promotion are promoted. The subattribute morale, measured on a zero to 10 scale, is the rating of the attitudes and feelings of the personnel about their work environment.

Allocation of employee time is measured by percent of productive effort. Items such as nonproductive meetings reduce the percent. The factor is subjectively ranked on a scale of zero to ten (ideal). These are defined to be zero as little or no productive effort, five is average productive effort for all organizations of this type and ten is nearly all effort is productive.

Money is a major factor composed of organizational and program budgets.

Organizational budget is measured by a ratio of actual budget to requested budget and may range from 75 to 110 percent.

Program budget is measured by the percentage of requested funding, and it may range from 75 to 110 percent.

Facilities has quality and space as measurable attributes.

Quality refers to the physical characteristics of the space such as noise level, air conditioning, communication and the like. This attribute is measured on a subjective scale from zero to ten.

Space is the average square feet per person available and may range from 60 to 130.

Development including acquisition is the major factor which refers to the actual work done on projects by inhouse/contracted people and the contractor. Development effectiveness is measured by performance and visibility attributes.

Due to the importance of performance, it is broken down into the subattributes of cost, schedule, and technical achievement. All three of these subattributes are measured as a percent of the original goals.

Visibility is a measure of the knowledge of managers about the project and project progress. This attribute is measured on the monthly report showing cost and schedule to earned value. It ranges from 50 to 100 percent.

Personal consists of two measureable attributes, job satisfaction and time allocation. Both factors are subjectively ranked on a scale of zero to ten.

Table 2 summarizes the attributs and gives the relative importance of each attribute and the value assigned to each attribute in Jan 80. The utility functions for each attribute are grouped in Appendix A.

Utility Functions

The eighteen measureable attributes identified in the preceding section must be functionally related to utility. In all cases, the minimum value for utility is zero and the maximum value is 1. For those attributes with a linear relation, the function is very straight forward. For the nonlinear functions a series of values was established and a quadratic or exponential curve fitted to the values. This approximation appeared to be close enough for practical evaluations. The utility functions are summarized in Table 3 and the final model in Table 4. The final model is a partially additive multiplicative model. A sample computation is shown in Appendix A. The model was also programmed into the computer and a sample is listed in Appendix B.

TABLE 4

COLONEL LINDSAY - ATTRIBUTES

ATTRIBUTE		MEASURE	RANGE	Ki	(Ui)Xi)
X_1	Personnel			.5	
X_{11}	Manning	Manyears Short	400 - 0	.6	$1-.0025\ (X_{11})$
X_{12}	Experience	Rate	0 - 3	.3	$.111\ (X_{12})^2$
X_{13}	Training	% On	0 - 5	.3	$.2\ (X_{13})$
X_{14}	Morale			.2	
X_{141}	Work Time	Hours/Week	50 - 40	.3	$1 - .1\ (X_{141} - 40)$
X_{142}	Awards	%/Year	0 - 5	.2	$.2\ (X_{142})$
X_{143}	Advancement Opportunity	Rate	0 - 5	.2	$.2\ (X_{143})$
X_{144}	Morale	Rank	0 - 10	.4	$.1\ X_{144}$
X_{15}	Allocate Time	Rank	0 - 10	.2	$.01\ (X_{15})^2$
X_2	Money			.6	
X_{21}	Organiza-tional	Budget/Request	75 - 110	.3	$.000816\ (X_{21} - 75)^2$
X_{22}	Programs	% Funded	75 - 110	.5	$.000816\ (X_{22} - 75)^2$
X_3	Facilities			.2	
X_{31}	Quality	Rank	0 - 10	.4	$.1\ X_{31}$
X_{32}	Space	Square Feet	60 - 130	.3	$1 - e^{-.0925(X_{32} - 60)}$
X_4	Development			.7	
X_{41}	Performance			.9	
X_{411}	Cost	% On	0 - 100	.3	$.0001\ (X_{4111})^2$

TABLE 4 (Cont'd)

ATTRIBUTE		MEASURE	RANGE	Ki	Ui(Xi)
X_{412}	Schedule	% On	0 - 100	.2	$.0001\ (X_{412})^2$
X_{413}	Technical Achievement	% On	0 - 100	.5	$.0001\ (X_{413})^2$
X_{42}	Visibility	Cost and Schedule	50 - 100	.1	$.02\ (X_{42}) - 1$
X_5	Personal			.25	
X_{51}	Job Satis-faction	Rank	0 - 10	.3	$.01\ (X_{51})^2$
X_{52}	Time	Rank	0 - 10	.3	$.01\ (X_{52})^2$

TABLE 5

COLONEL LINDSAY: UTILITY FUNCTIONS

ATTRIBUTE		MEASURE	RANGE	Present Xi	Present U*	New Xi	New Ui
X_{11}	Manning	Manyears Short (400-0)	$1 - .0025\ (X_{11})$				
X_{12}	Experience	Rate (0-3)	$.111\ (X_{12})^2$				
X_{13}	Training	% On (0-5)	$.2\ (X_{13})$				
X_{141}	Work Time	Hours/Week (50-40)	$1 - .1\ (X_{141} - 40)$				
X_{142}	Awards	% Year (0-5)	$.2\ (X_{142})$				
X_{143}	Advancement Opportunity	Rate (0-5)	$.2\ (X_{143})$				
X_{144}	Morale	Rank (0-10)	$.1\ (X_{144})$				
X_{15}	Allocate Time	Rank (0-10)	$.01\ (X_{15})^2$				
X_{21}	Organizational Budget	Budget/Request (75-110)	$.000816\ (X_{21} - 75)^2$				
X_{22}	Programs Budget	% Funded (75-110)	$.000816\ (X_{22} - 75)^2$				
X_{31}	Quality	Rank (0-10)	$.1\ X_{31}$				
X_{32}	Space	Square Feet/ Person (60-130)	$1 - e^{-.0925\ (X_{32} - 50)}$				
X_{411}	Cost	% On	$.0001\ (X_{411})^2$				
X_{412}	Schedule	% On	$.0001\ (X_{412})^2$				
X_{413}	Technical Achievement	% On	$.0001\ (X_{413})^2$				

TABLE 5 (Cont'd)

ATTRIBUTE		MEASURE	RANGE	Present Xi	Present U*	New Xi	New Ui
X_{42}	Visibility	Cost & Schedule (50-100)	$.02X_4 - 1$				
X_{51}	Job Satis-faction	Rank (0-10)	$.01\ (X_{51})^2$				
X_{52}	Time	Rank (0-10)	$.01\ (X_{52})^2$				

*Ui must be between 0 and 1

TABLE 6

COLONEL LINDSAY'S MODEL

$U_x = .2222\ U_1 + .2666\ U_2 + .0888\ U_3 + .3111\ U_4 + .1111\ U_5$

$U_1 = .125\ U_{15} + .875\ U_{Z1}$

$U_{Z1} = [(1 - .4\ U_{11})\ (1 - .2\ U_{12})\ (1 - .2\ U_{13})\ (1 - .1333\ U_{14}) - 1]/-.6667$

$U_{14} = .273\ U_{141} + .182\ U_{142} + .182\ U_{143} + .363\ U_{144}$

$U_2^* = .3\ U_{21} + .5\ U_{22} + .2\ U_{22})$

$U_3 = .572\ U_{31} + .428\ U_{32}$

$U_4 = .1\ U_{42} + .27\ U_{411} + .18\ U_{412} + .45\ U_{413}$

$U_5^* = .3\ U_{51} + .3\ U_{52} + .4\ U_{51}\ (U_{52})$

*Alternate Form

$U_2 = [(1 + .4\ U_{21})\ (1 + .6667\ U_{22}) - 1]/1.3333$

$U_5 = [(1 + 1.333\ U_{51})\ (1 + 1.333\ U_{52}) - 1]/4.444$

TABLE 2

COL. LINDSAY

Name	Attribute Number	Units	Range	Ki	Current Status	Utility Functions	Current Utility
Personnel	x_1			.5			$u(x_1) = .4$
Manning	x_{11}	Manyears Short	400-0	.6	360	$u(x_{11}) = 1 - .0025x_{11}$	$u(x_{11}) = .1$
Experience	x_{12}	Rate	0-3	.3	2	$u(x_{12}) = .111(x_{12})^2$	$u(x_{12}) = .444$
Training	x_{13}	%	0-5	.3	2.2	$u(x_{13}) = .\ x_{13}$	$u(x_{13}) = .44$
Morale	x_{14}			.2			$u(x_{14}) = .642$
Work Time	x_{141}	Hours/Week	50-40	.3	44	$u(x_{141}) = 1 - .1(x_{141} - 40)$	$u(x_{141}) = .6$
Awards	X_{142}	%/Year	0-5	.2	5	$u(x_{142}) = .2x_{142}$	$u(x_{142}) = 1$
Advancement Opportunity	x_{143}	Rate	0-5	.2	1.5	$u(x_{143}) = .2x_{143}$	$u(x_{143}) = .03$
Morale	x_{144}	Rank	0-10	.4	8	$u(x_{144}) = .1x_{144}$	$u(x_{144}) = .8$
Allocate Time	x_{15}	Rank	0-10	.2	6	$u(x_{15}) = .01(x_{15})^2$	$u(x_{15}) = .36$
Money	x_2			.6			$u(x_2) = .09$
Organizational	x_{21}	Budget/Request	75-110	.3	75	$u(x_{21}) = .000816(x_{21} - 75)^2$	$u(x_{21}) = 0$

TABLE 2 (continued)

Name	Attribute Number	Units	Range	Ki	Current Status	Utility Functions	Current Utility
Programs	x_{22}	% Funded	75-110	.5	90	$u(x_{22}) = .000816(x_{22}-75)^2$	$u(x_{22}) = .18$
Facilities	x_3			.2			$u(x_3) = .76$
Quality	x_{31}	Rank	0-10	.4	6	$u(x_{31}) = .1x_{31}$	$u(x_{31}) = .60$
Space	x_{32}	Square Feet/	60-130	.3	100	$u(x_{32}) = 1-e^{-.0925(x_{32}-60)}$	$u(x_{32}) = .97$
Development	x_4			.7			$u(x_4) = .225$
Performance	x_{41}			.9			$u(x_{41}) = .25$
Cost	x_{411}	% On	0-100	.3	50	$u(x_{411}) = .0001(x_{411})^2$	$u(x_{411}) = .25$
Schedule	x_{412}	% On	0-100	.2	50	$u(x_{412}) = .0001(x_{412})^2$	$u(x_{412}) = .25$
Technical Achievement	x_{413}	% On	0-100	.5	50	$u(x_{413}) = .0001(x_{413})^2$	$u(x_{413}) = .25$
Visibility	x_{42}	Cost & Schedule	50-100	.1	50	$u(x_{42}) = .02(x_{42})-1$	$u(x_{42}) = 0$
Personal	x_5			.25			$u(x_5) = .175$
Job Satisfaction	x_{51}	Rank	0-10	.3	5	$u(x_{51}) = .01(x_{51})^2$	$u(x_{51}) = .25$
Time	x_{52}	Rank	0-10	.3	5	$u(x_{52}) = .01(x_{52})^2$	$u(x_{52}) = .25$
							$u(x) = .27$

TABLE 3

COL. LINDSAY

Attribute Number	Name	Units	Range	Utility Function	Present x_i	Present $u(x_i)$	New x_i	New $u(x_i)$
x_{11}	Manning	Manyears Short	400-0	$1-.0025x_{11}$	360	.1		
x_{12}	Experience	Rate	0-3	$.111(x_{12})^2$	2	.444		
x_{13}	Training	% On	0-5	$.2x_{13}$	2.2	.44		
x_{141}	Work Time	Hours/Week	50-40	$1-.1(x_{141}-40)$	44	.6		
x_{142}	Awards	%/Year	0-5	$.2x_{142}$	5	1		
x_{143}	Advancement Opportunity	Rate	0-5	$.2_x{}^{143}$	1.5	.03		
x_{144}	Morale	Rank	0-10	$.1x_{144}$	8	.8		
x_{15}	Allocate Time	Rank	0-10	$.01(x_{15})^2$	6	.36		
x_{21}	Organizational Budget	Budget/Request	75-110	$.000816(x_{21}-75)^2$	75	0		
x_{22}	Programs Budget	% Funded	75-110	$.000816(x_{22}-75)^2$	90	.18		
x_{31}	Quality	Rank	0-10	$.1x_{31}$	6	.6		

TABLE 3 (continued)

Attribute Number	Name	Units	Range	Utility Function	Present x_i	Present $u(x_i)$	New x_i	New $u(x_i)$
x_{32}	Space	Square Feet/Person	60-130	$1-e^{-.0925(x_{32}-60)}$	100	.975		
x_{411}	Cost	% On	0-100	$.0001(x_{411})^2$	50	.25		
x_{412}	Schedule	% On	0-100	$.0001(x_{412})^2$	50	.25		
x_{413}	Technical Achievement	% On	0-100	$.0001(x_{413})^2$	50	.25		
x_{42}	Visibility	Cost & Schedule	50-100	$.02(x_{42})-1$	50	0		
x_{51}	Job Satisfac-tion	Rank	0-10	$.01(x_{51})^2$	5	.25		
x_{52}	Time	Rank	0-10	$.01(x_{52})^2$	5	.25		

TABLE 4

COL. LINDSAY

$$u(x) = .2222u(x_1) + .2666u(x_2) + .0888u(x_3) + .3111u(x_4) + .1111u(x_5)$$

$$= .2222(.4) + .2666(.09) + .0888(,761) + .3111(.225) + .1111(.175)$$

$$= .27$$

$$u(x_1) = .875u(x_{21}) + .125(u(x_{15}))$$

$$= .875(.406) + .125(.36) = .4$$

$$u(x_{21}) = [(1-.4u(x_{11}))(1-.2u(x_{12}))(1-2u(x_{13}))(1-.1333u(x_{14}))-1]/-.6667$$

$$= [(1-.4(.1))(1-.2(.444))(1-.2(.44))(1-.1333(.642))-1]/-.6667$$

$$= .406$$

$$u(x_{14}) = .273u(x_{141}) + .182u(x_{142}) + .182u(x_{143}) + .363u(x_{144})$$

$$= .273(.6) + .182(1) + .182(.03) + .363(.8)$$

$$= .642$$

$$u(x_2)^* = .3u(x_{21}) + .5u(x_{22}) + .2u(x_{21})u(x_{22})$$

$$= .3(0) + .5(.18) + 2(0)(.18)$$

$$= .09$$

$$u(x_3) = .572u(x_{31}) + .428u(x_{32})$$

$$= .572(.6) + .428(.975) = .761$$

$$u(x_4) = 9u(x_{41}) + .1u(x_{42})$$

$$= .9(.25) + .1(0) = .225$$

$$u(x_{41}) = 3u(x_{411}) + 2u(x_{412}) + .5u(x_{413})$$

$$- .3(.25) + .2(.25) + .5(.25) = .25$$

TABLE 4 (continued)

$$u(x_5)^* = .3u(x_{51}) + .3u(x_{52}) + .4u(x_{51})u(x_{52})$$

$$= .3(.25) + .3(.25) + .4(.25)(.25) = .175$$

*Alternate Form

$$u(x_2) = [(1 + .6667u(x_{21}))(1 + .6667u(x_{22})) - 1]/1.3333$$

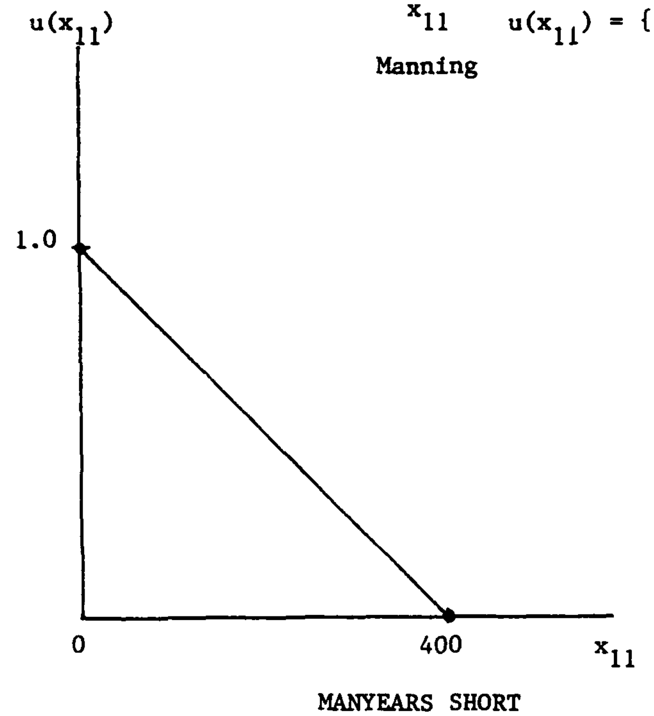
$$u(x_5) = [(1 + 1.333u(x_{51}))(1 + 1.333u(x_{52})) - 1]/4.444$$

COL. LINDSAY - ATTRIBUTES

x_{11}

Manning

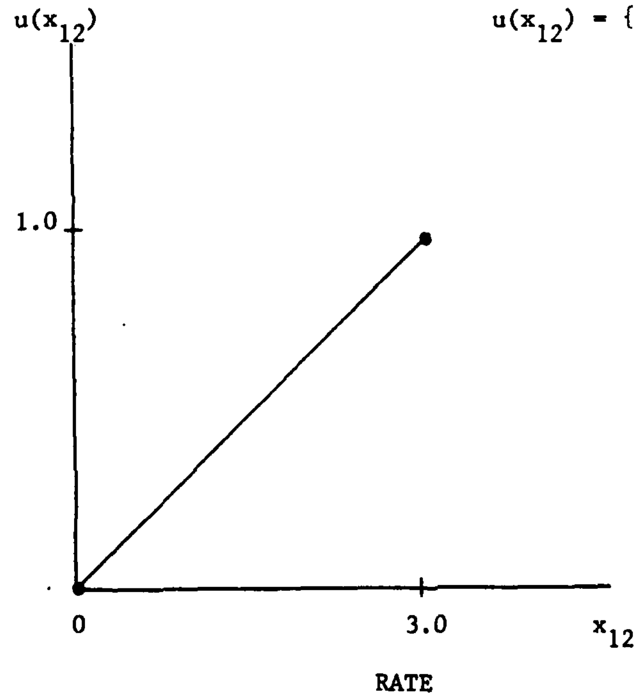
$$u(x_{11}) = \begin{cases} 1-.0025x_{11}, & 0 \leq x_{11} \leq 400 \\ 1, & x_{11} > 400 \end{cases}$$



x_{12}

Experience

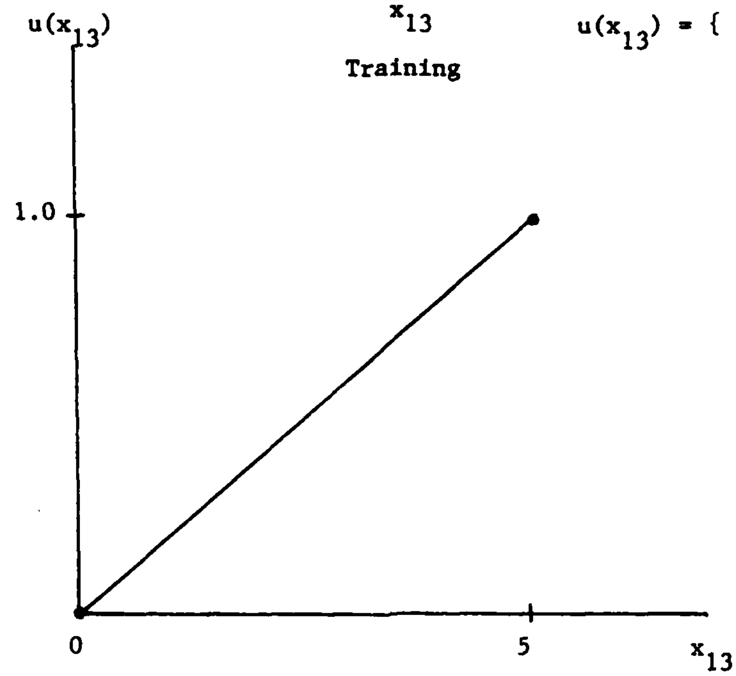
$$u(x_{12}) = \begin{cases} .111(x_{12})^2, & 0 \leq x_{12} \leq 3 \\ 1, & x_{12} > 3 \end{cases}$$



x_{13}

Training

$$u(x_{13}) = \begin{cases} .2x_{13}, & 0 \le x_{13} \le 5 \\ 1, & x_{13} > 5 \end{cases}$$

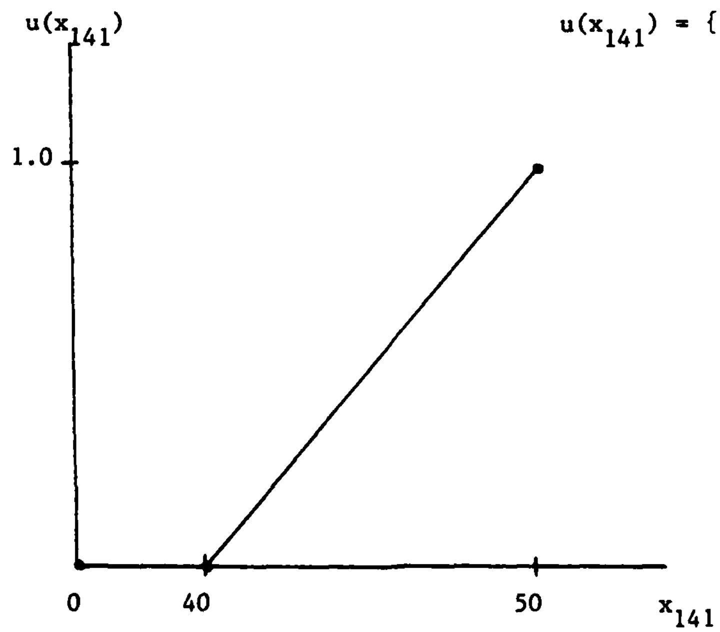


PER CENT ON

x_{141}

Morale - Work Time

$$u(x_{141}) = \begin{cases} 1, & x_{141} > 50 \\ 1-.1(x_{141}-40), & 40 \le x_{141} \le 50 \\ 0, & x_{141} \le 40 \end{cases}$$



AVERAGE WEEKLY HOURS

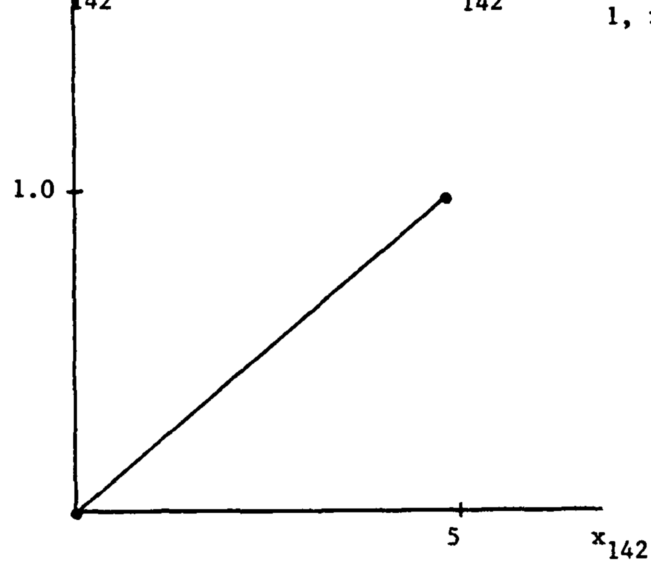
COL. LINDSAY (continued)

x_{142}

Awards

$u(x_{142})$

$$u(x_{142}) = \begin{cases} .2x_{142}, & 0 \le x_{142} \le 5 \\ 1, & x_{142} > 5 \end{cases}$$



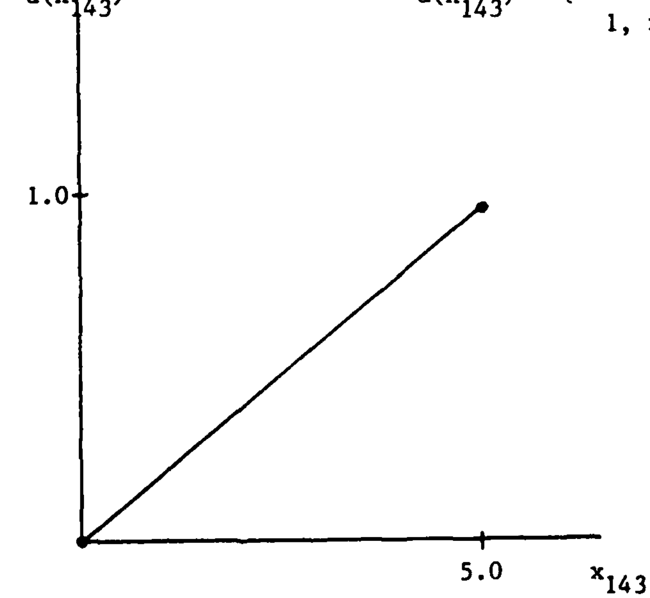
PER CENT PER YEAR

x_{143}

Advancement Opportunity

$u(x_{143})$

$$u(x_{143}) = \begin{cases} .2x_{143}, & 0 \le x_{143} \le 5 \\ 1, & x_{143} > 5 \end{cases}$$

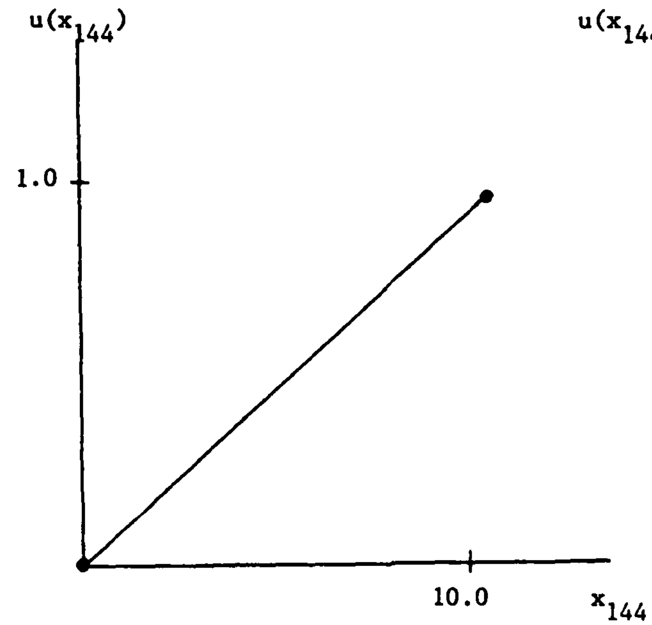


RATE

x_{144}

Morale

$$u(x_{144}) = \begin{cases} .1x_{144}, & 0 \leq x_{144} \leq 10 \\ 1, & x_{144} > 10 \end{cases}$$

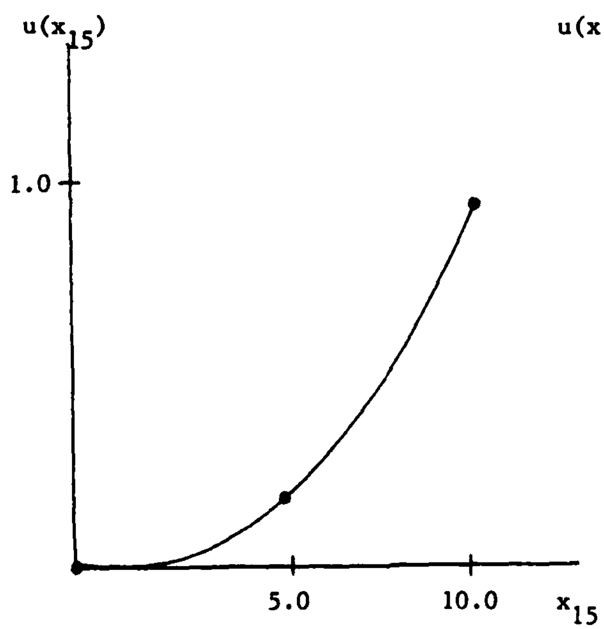


RANK

x_{15}

Allocate Time

$$u(x_{15}) = \begin{cases} .01x_{15}^2, & 0 \leq x_{15} \leq 10 \\ 1, & x_{15} > 10 \end{cases}$$



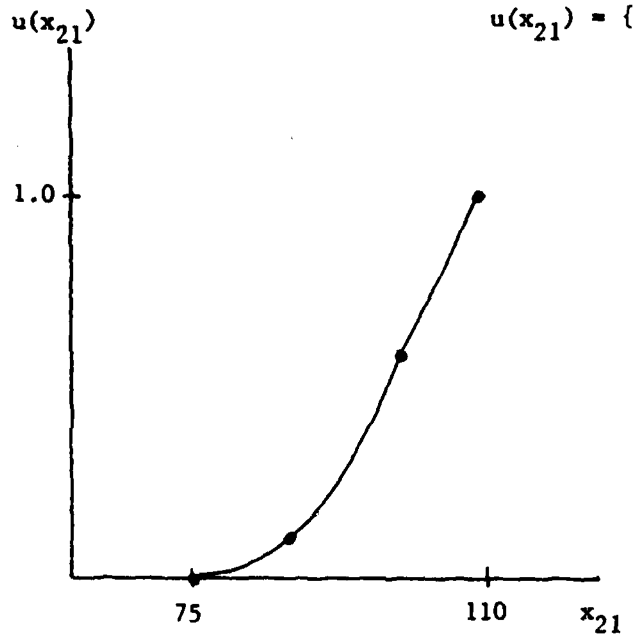
RANK

COL. LINDSAY (continued)

x_{21}

Organizational Budget

$$u(x_{21}) = \begin{cases} 0, & x_{21}<75 \\ .000816(x_{21}-75)^2, & 75\leq x_{21}\leq 110 \\ 1, & x_{21}>110 \end{cases}$$

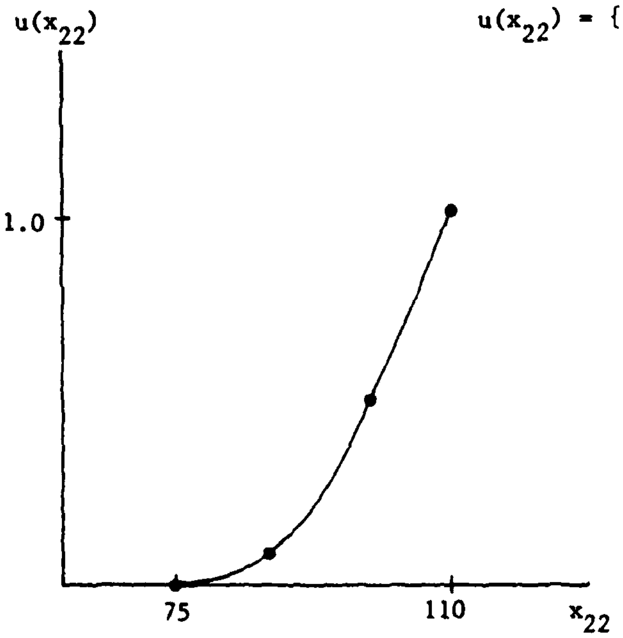


BUDGET/REQUESTED

x_{22}

Programs Budget

$$u(x_{22}) = \begin{cases} 0, & x_{22}<75 \\ .000816(x_{22}-75)^2, & 75\leq x_{22}\leq 110 \\ 1, & x_{22}>110 \end{cases}$$

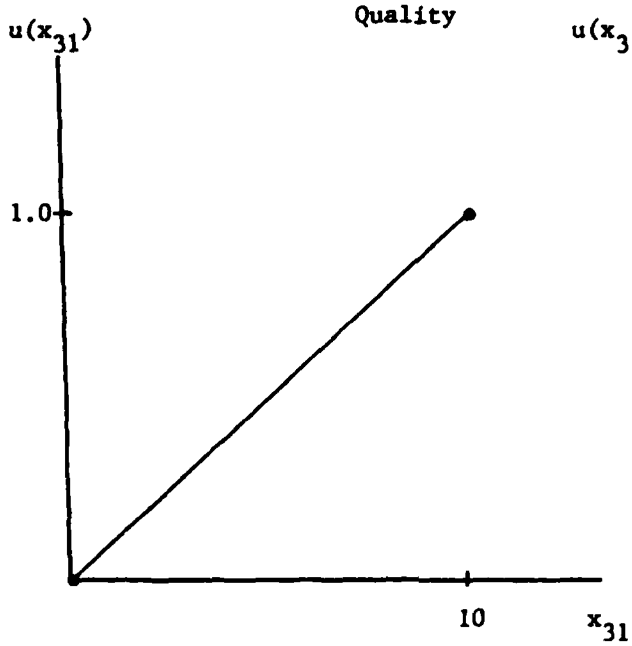


BUDGET/REQUESTED

x_{31}

Quality

$$u(x_{31}) = \begin{cases} .1x_{31}, & 0 \leq x_{31} \leq 10 \\ 1, & x_{31} > 10 \end{cases}$$

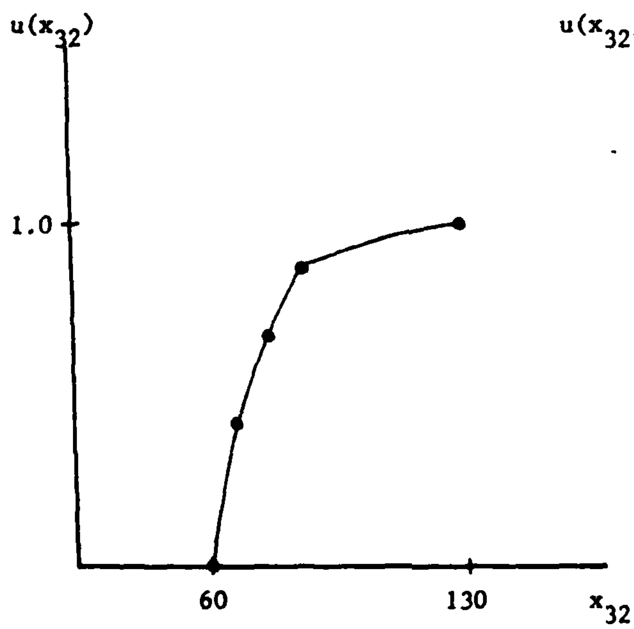


RANK

x_{32}

Space

$$u(x_{32}) = \begin{cases} 0, & x_{32} < 60 \\ 1-e^{-.0925(x_{32}-60)} & \text{For } 60 \leq x_{32} \leq 130 \\ 1, & x_{32} > 130 \end{cases}$$

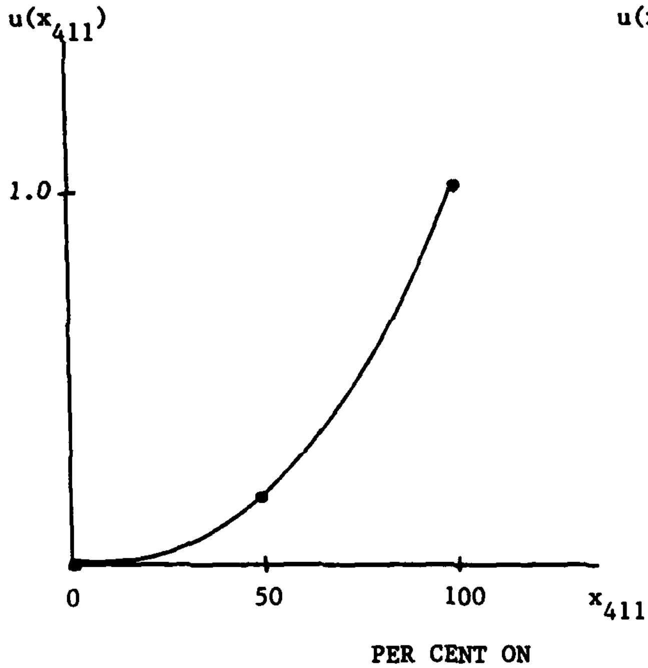


SQUARE FEET PER PERSON

x_{411}

Cost

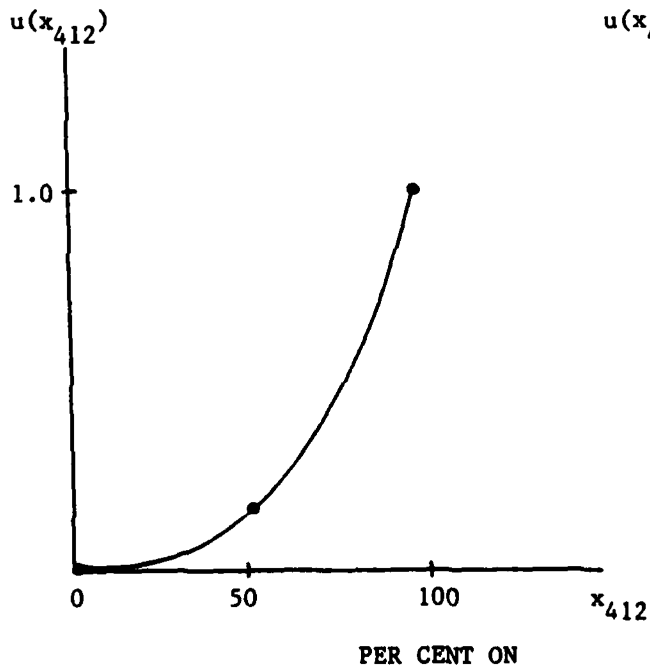
$$u(x_{411}) = \begin{cases} .0001(x_{411})^2, & 0 \le x_{411} \le 100 \\ 1, & x_{411} > 100 \end{cases}$$



x_{412}

Schedule

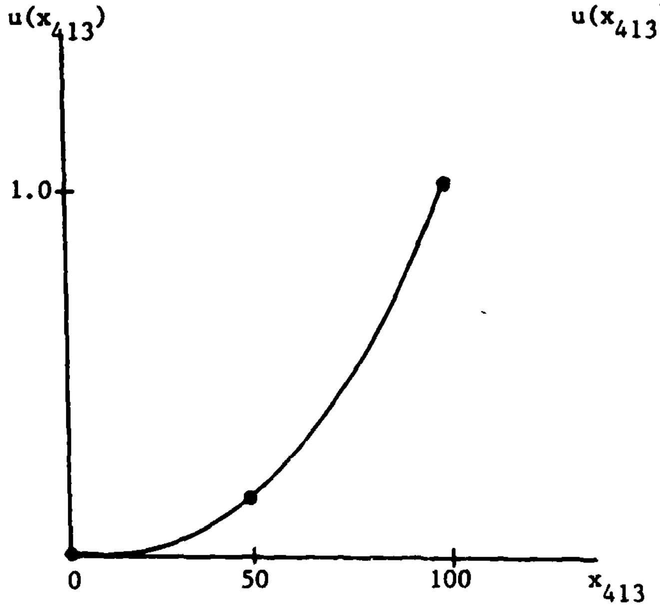
$$u(x_{412}) = \begin{cases} .0001(x_{412})^2, & 0 \le x_{412} \le 100 \\ 1, & x_{412} > 100 \end{cases}$$



x_{413}

Technical Achievement

$$u(x_{413}) = \begin{cases} .0001(x_{413})^2, & 0 \leq x_{143} \leq 100 \\ 1, & x_{413} > 100 \end{cases}$$

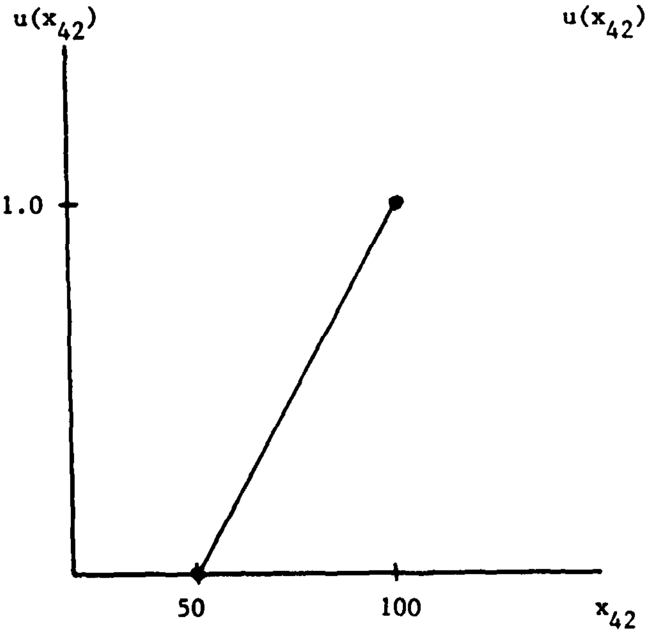


PER CENT ON

x_{42}

Visibility

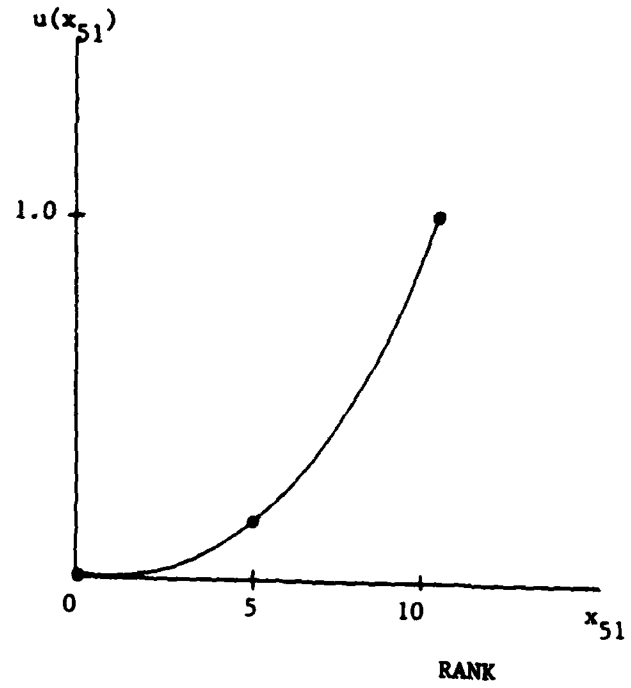
$$u(x_{42}) = \begin{cases} 0, & x_{42} < 50 \\ .02x_{42} - 1, & 50 \leq x_{42} \leq 100 \\ 1, & x_{42} > 100 \end{cases}$$



COST AND SCHEDULE

x_{51}

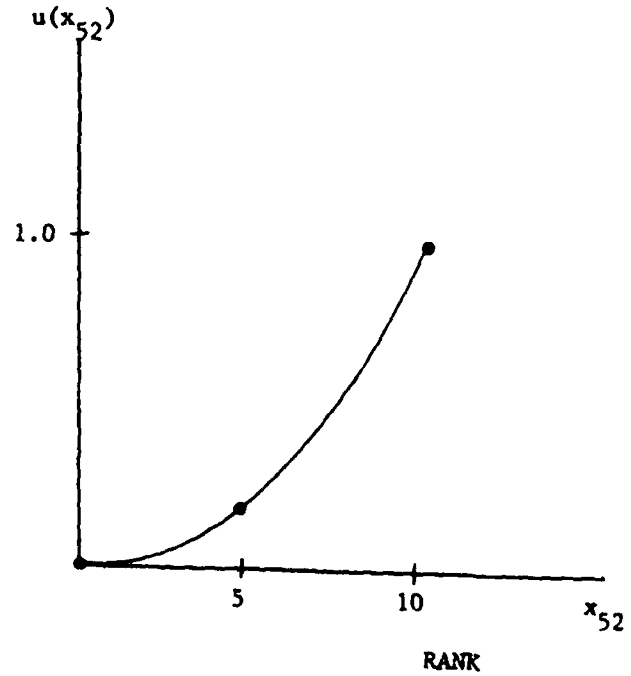
Job Satisfaction



$$u(x_{51}) = \begin{cases} .01(x_{51})^2, & 0 \leq x_{51} \leq 10 \\ 1, & x_{51} > 10 \end{cases}$$

x_{52}

Time



$$u(x_{52}) = \begin{cases} .01(x_{52})^2, & 0 \leq x_{52} \leq 10 \\ 1, & x_{52} > 10 \end{cases}$$

THE COMPUTER SCIENCE (KR) MODEL

Mr. James L. Thoreen, former Director of Computer Sciences, has a very strong background in computer sciences and mathematics. He has worked on computers since the 1950s and received his masters degree in mathematics from Florida State University. He previously directed all the computer science activities for Eglin Air Force Base. The Computer Sciences Directorate has over 52 computers including the IBM 360, CDC 6600, and Burroughs 4700. Mr. Thoreen stated that the Computer Science mission is to provide computer and mathematical support to AD and the Eglin AFB tenants. He reported to Colonel Robbins, Chief of Staff, AD, and had over 200 people reporting to him.

Attributes and Model for Mr. Thoreen

The mission of the Computer Science Directorate, KR, is to provide support in the computer solution to problems. Since Computer Science's roll is support, the factors differ greatly from KR to SD, but the same basic procedures were used to determine the model for computer science as was used for armament development.

Attribute Definition

Twenty-one attributes were defined by Mr. Thoreen. The major categories are provide service, maintain security, personnel, and development. The hierarchy for Mr Thoreen is given in Figure 3. The decisions that Mr. Thoreen considers important are listed in Table 5.

Providing service is the primary function of the computer science directorate and is broken into six major components - Computer Operations, Data Reduction, Modeling, Hardware, Real Time Support, and Physical Facilities. Computer operations has subattributes of technical or Burroughs, the base record system. Technical is further divided into payment for service and customer satisfaction. Real time support is broken down into capacity to perform simultaneous missions and failures on missions.

Security is divided between property damage which may be accidental or deliberate and information which may be classified as private.

Personnel is broken down into training, morale, motivation, and recruitment. Recruitment is further divided into timely, quality and affirmative action components.

Development of the Computer Science Directorate is a major factor considering plans and thoughts from the present to 10 years ahead.

Mr. Thoreen defined the specific attributes as follows:

Pay under technical computer operations is the percent of the costs paid for by users of the service. Ideally 125 percent of the costs would be paid to permit expansion and improved capabilities of the service.

Customer satisfaction with computer services was objectively ranked on a scale of zero to five with two having no utility. Two

FIGURE 3
THOREEN HIERARCHY

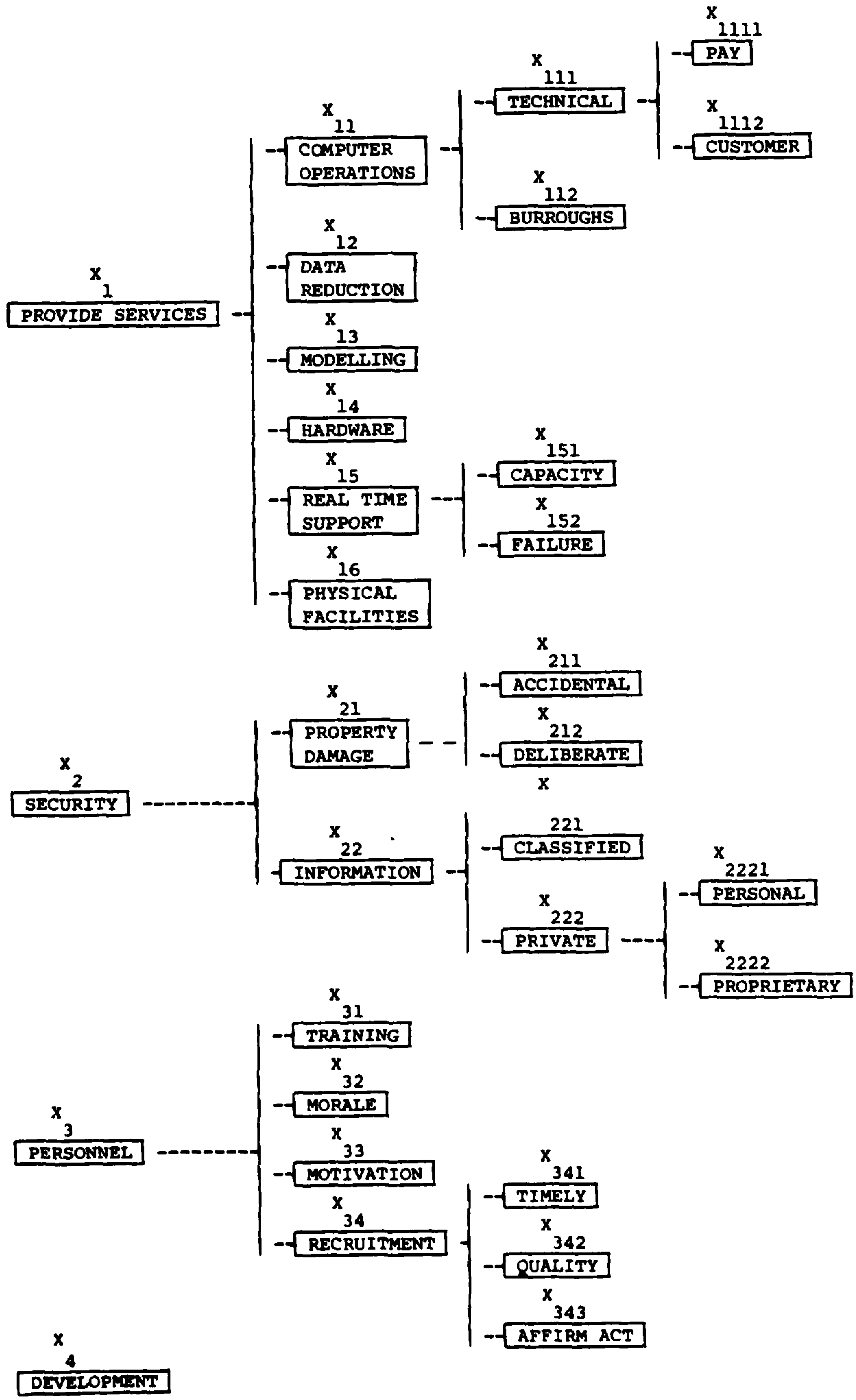


TABLE 6

MR. THOREEN'S DECISIONS

1. One time decision to get a large computer or not.
2. Organizational effectiveness.

<u>Variable</u>	
D_1	Personnel
D_{11}	Time Allocation
D_{12}	Selection [Competence, Grade, EEO]
D_{13}	Recruitment
D_{14}	Dismiss or Withhold Raise
D_{15}	Install Morale Booster
D_2	Computer Equipment Approval
D_3	Operational
D_{31}	Set Priorities
D_{32}	Resolve Conflicts
D_4	Strategy
D_{41}	Jobs to Accept
D_{42}	Computer Configuration
D_{43}	Building Specs

would reflect dissatisfaction but no action by the customers to correct the situation.

Burroughs or nontechnical customer satisfaction was measured the same as the technical customers on a scale of zero to 5.

Data reduction was measured by the percent of work done on time and would range from 50 to 100 percent.

Modeling also was based on percent of occasions that the analysts met the required need and could vary from 50 to 100 percent.

Hardware sufficient to do the requested jobs was subjectively rated on a scale of zero to 10 with five being unacceptable.

Real time support capacity was rated by the number of simultaneous missions the system could handle with a range from zero to six.

Real time failures per year measured the ability to accomplish a mission. An average of one failure per year was unacceptable.

Physical facilities for personnel and hardware was subjectively rated on a scale of zero to 10.

Property damage whether accidental or deliberate was rated as to vulnerability on a scale of zero to 10.

Classified information violations of one per year was unacceptable as was the violation of personal or proprietary information on private parties.

Training was judged on percent of total time spent on training. Ideally 6 percent of the time would be spent on training.

Morale was subjectively ranked on a scale of zero to ten.

Motivation reflected the number of people who were highly motivated and could be counted on to keep everything moving at high efficiency. If 20 percent of the people were highly motivated the operation would be ideal. If more than 20 percent, conflicts might arise.

Timely recruitment is the average number of days to fill a vacancy and ranges from zero to 60.

Quality recruitment refers to the percent and potential capability to do computer or mathematics work and was subjectively rated on a scale of zero to 3.

Affirmative action referes to number of various minorities on the work force. Ideally the percent would be the same as the national average of the minority to the total population.

The final attribute was development, which was measured by the number of years ahead the planning for the future are done. This might range from zero to ten years.

The function for each of the attributes is shown in Tables 6 and 7 while the relationship of factors is expressed in the model shown in

Table 8. The overall model is a partially additive multiplicative model. No attributes were considered to be conditionally dependent on any other.

All the attributes and a sample computation are shown in Appendix A.

TABLE 7

MR THOREEN'S FACTORS

VARIABLE		ATTRIBUTE	WEIGHT	LOW	NOW	HIGH	U
X_1	Provide Service		.3				
X_{11}	Computer Operations		.8				
X_{111}	Technical		.7				
X_{1111}	Pay	%	.5	75,175	82	125	$e^{-\frac{(X_{1111}-125)^2}{16}}$
X_{1112}	Customer	Rank	.5	2	3	5	-.667+.333X1112
X_{112}	Burroughs	Rank	.6	2	4	5	$-.667+.333X_{112}$
X_{12}	Data Reduction	% On Time	.5	50	80	100	$-1 + .02X_{12}$
X_{13}	Modeling	% Meets	.1	50	90	100	$-1 + .02X_{13}$
X_{14}	Hardware	Sufficient	.08	5	8	10	$.1X_{14}$
X_{15}	Real Time Support		.7				
X_{151}	Capacity	Simultaneous	.5	0	3	6	$.163X_{151}$
X_{152}	Failure	Aborts/year	.7	1	1	0	$1-X_{152}$
X_{16}	Physical Facilities	Rating	.05	0	9	10	$-1X_{16}$
X_2	Security		.3				
X_{21}	Property Damage		.3				
X_{211}	Accidental	Vulnerability	.8	0	9	10	$.1X_{211}$

TABLE 7 (Cont'd)

VARIABLE		ATTRIBUTE	WEIGHT	LOW	NOW	HIGH	U
X_{212}	Deliberate	Vulnerability	.8	0	5	10	$.1X_{212}$
X_{22}	Information		.8				
X_{221}	Classified	Violations/Year	.8	1	1	0	$1-X_{221}$
X_{222}	Private		.3				
X_{2221}	Personal	Violations/Year	.6	1	1	0	$1-X_{2221}$
X_{2222}	Proprietary	Violations/Year	.5	1	1	0	$1-X_{2222}$
X_3	Personnel		.05				
X_{31}	Training	% Of Time	.3	3,9	3	6	$e^{-(X_{31}-6)^2}$
X_{32}	Morale	Rank	.1	0	9	10	$.1X_{32}$
X_{33}	Motivation	% People	.1	0	20	20	$.05X_{33}$
X_{34}	Recruitment		.2				
X_{341}	Timely	Days	.5	60	60	0	$1-.01667X_{341}$
X_{342}	Quality	Rank	.7	0	2	3	$.333X_{342}$
X_{343}	Affirm Act	%	.7	$\pm$0+Nat*	70	Nat	$e^{-\frac{(X_{343}-\text{Nat})^2}{3}}$
X_4	Development	Years Ahead	.1	0	5	10	$.1X_4$

*Nat = National Average %

TABLE 8

MR THOREEN'S ATTRIBUTES

VARIABLE		M	Present Xi	Present U(Xi)	New Xi	New U(Xi)
X_{1111}	Pay	$e^{-\frac{(X_{1111}-125)^2}{16}}$				
X_{1112}	Customer	$-.667+.333X_{1112}$				
X_{112}	Burroughs	$-.667+.333X_{112}$				
X_{12}	Data Reduction	$-1 + .02X_{12}$				
X_{13}	Modelling	$-1 + .02X_{13}$				
X_{14}	Hardware	$.1X_{14}$				
X_{151}	Capacity	$.163X_{151}$				
X_{152}	Failure	$1-X_{152}$				
X_{16}	Physical Facilities	$-1X_{16}$				
X_{211}	Accidental	$.1X_{211}$				
X_{212}	Deliberate	$.1X_{212}$				
X_{221}	Classified	$1-X_{221}$				
X_{2221}	Personal	$1-X_{2221}$				
X_{2222}	Proprietary	$1-X_{2222}$				
X_{31}	Training	$e^{-(X_{31}-6)^2}$				
X_{32}	Morale	$.1X_{32}$				
X_{33}	Motivation	$.05X_{33}$				
X_{341}	Timely	$1-.01667X_{341}$				

TABLE 8 (Cont'd)

VARIABLE		M	Present Xi	Present U(Xi)	New Xi	New U(Xi)
X_{342}	Quality	$.333X_{342}$				
X_{343}	Affirm Act	$e^{-\frac{(X_{343}-Nat)^2}{3}}$				
X_4	Development	$.1X_4$				

TABLE 9

MR THOREEN'S MODEL

$U(x) = .4\ U_1 + .4\ U_2 + .0667\ U_3 + .1333\ U_4$

$U_1 = [(1-.752U_{11})(1-.47U_{12})(1-.094U_{13})(1-.015U_{14})(1-.658U_{15})(1-.04U_{16})-1]/-.97$

$U_{11} = .538\ U_{111} + .462\ U_{112}$

$U_{111} = .5\ U_{1111} + .5\ U_{1112}$

$U_{15} = [(1 - .0285\ U_{151})\ (1 - .04\ U_{152}) - 1]/-.057$

$U_2 = ,273\ U_{21} + .727\ U_{22}$

$U_{21} = .5\ U_{211} + .5\ U_{212}$

$U_{22} = .7\ U_{221} + .3\ U_{222}$

$U_{222} = [(1 - .2\ U_{2221})\ (1 - .163\ U_{2222}) - 1]/-.333$

$U_3 = [(1 + .456\ U_{31})(1 + .152\ U_{32})(1 + .152\ U_{33})(1 + .304\ U_{34}) - 1]/1.52$

$U_{34} = .263\ U_{341} + .368\ U_{343} + .368\ U_{343}$

TABLE 10

MR. THOREEN ATTRIBUTES

Name	Attribute Number	Units	Range	Ki	Current Status	Utility Functions	Current Utility
Provide Services	x_1			.3			$u(x_1)=.5336$
Computer Operations	x_{11}			.8			$u(x_{11})=.4$
Technical	x_{111}			.7			$u(x_{111})=.17$
Pay	x_{1111}	%	75,175-125	.5	82	$u(x_{1111})=e^{-(\frac{x_{1111}-125}{16})^2}$	$u(x_{1111})=.0007$
Customer	x_{1112}	Rank	2-5	.5	3	$u(x_{1112})=-.6667+.3333x_{1112}$	$u(x_{1112})=.3333$
Burroughs	x_{112}	Rank	2-5	.6	4	$u(x_{112})=-.6667+.3333x_{112}$	$u(x_{112})=.6665$
Data Reduction	x_{12}	% On Time	50-100	.5	80	$u(x_{12})=-1+.02x_{12}$	$u(x_{12})=.6$
Modelling	x_{13}	%	50-100	.1	90	$u(x_{13})=-1+.02x_{13}$	$u(x_{13})=.8$
Hardware	x_{14}	Sufficiency	0-10	.08	8	$u(x_{14})=.1x_{14}$	$u(x_{14})=.8$
Real Time Support	x_{15}			.7			$u(x_{15})=.2445$
Capacity	x_{151}	Simultaneous	0-6	.5	3	$u(x_{151})=.163x_{151}$	$u(x_{151})=.489$
Failure	x_{152}	Aborts/Year	1-0	.7	1	$u(x_{152})=1-x_{152}$	$u(x_{152})=0$

TABLE 10 (continued)

Name	Attribute Number	Units	Range	Ki	Current Status	Utility Functions	Current Utility
Physical Facilities	x_{16}	Rating	0-10	.05	9	$u(x_{16}) = .1x_{16}$	$u(x_{16}) = .9$
Security	x_2			.3			$u(x_2) = .19$
Property Damage	x_{21}			.3			$u(x_{21}) = .7$
Accidental	x_{211}	Vulnerability	0-10	.8	9	$u(x_{211}) = .1x_{211}$	$u(x_{211}) = .9$
Deliberate	x_{212}	Vulnerability	0-10	.8	5	$u(x_{212}) = .1x_{212}$	$u(x_{212}) = .5$
Information	x_{22}			.8			$u(x_{22}) = 0$
Classified	x_{221}	Violations/Year	1-0	.8	1	$u(x_{221}) = 1-x_{221}$	$u(x_{221}) = 0$
Private	x_{222}			.3			$u(x_{222}) = 0$
Personal	x_{2221}	Violations/Year	1-0	.6	1	$u(x_{2221}) = 1-x_{2221}$	$u(x_{2221}) = 0$
Proprietary	x_{2222}	Violations/Year	1-0	.5	1	$u(x_{2222}) = 1-x_{2222}$	$u(x_{2222}) = 0$
Personnel	x_3			.05			$u(x_3) = .34$
Training	x_{31}	% Of Time	3,9-6	.3	3	$u(x_{31}) = e^{-(x_{31}-6)^2}$	$u(x_{31}) = 0$
Morale	x_{32}	Rank	0-10	.1	9	$u(x_{32}) = .1x_{32}$	$u(x_{32}) = .9$
Motivation	x_{33}	Rating % People	0-20	.1	20	$u(x_{33}) = .05x_{33}$	$u(x_{33}) = 1$
Recruitment	x_{34}			.2			$u(x_{34}) = .53$

TABLE 10 (continued)

Name	Attribute Number	Units	Range	Ki	Current Status	Utility Functions	Current Utility
Timely	x_{341}	Days	60-0	.5	60	$u(x_{341}) = 1-.01667x_{341}$	$u(x_{341}) = 0$
Quality	x_{342}	Rank	0-3	.7	2	$u(x_{342}) = .333x_{342}$	$u(x_{342}) = .6666$
Affirm. Act.	x_{343}	%	±9+Nat. Avg-Nat. Avg	.7	70	$u(x_{343}) = {}^{*}e^{-\left(\frac{x_{343}-\mu_{343}}{3}\right)^2}$	$u(x_{343}) = .06$
Development	x_4	Years Ahead	0-10	.1	5	$u(x_4) = .1x_4$	$u(x_4) = .5$
							$u(x) = .3788$

$^{*}\mu_{343}$ = National Average

TABLE 11

MR. THOREEN UTILITY FUNCTIONS

Attribute Number	Name	Units	Range	Utility Function	Present x_i	Present $u(x_i)$	New x_i	New $u(x_i)$
x_{1111}	Pay	%	75,175-125	$e^{-\left(\frac{x_{1111}-125}{16}\right)^2}$	82	.0007		
x_{1112}	Customer	Rank	2-5	$-.6667+.3333x_{1112}$	3	.3333		
x_{112}	Burroughs	Rank	2-5	$-.6667+.3333x_{112}$	4	.6665		
x_{12}	Data Reduction	% On Time	50-100	$-1+.02x_{12}$	80	.6		
x_{13}	Modelling	%	50-100	$-1+.02x_{13}$	90	.8		
x_{14}	Hardware	Sufficiency	5-10	$.1x_{14}$	8	.8		
x_{151}	Capacity	Simultaneous	0-6	$.163x_{151}$	3	.489		
x_{152}	Failure	Aborts/Year	1-0	$1-x_{152}$	1	0		
x_{16}	Physical Facilities	Rating	0-10	$.1x_{16}$	9	.9		
x_{211}	Accidental	Vulnerability	0-10	$.1x_{211}$	9	.9		
x_{212}	Deliberate	Vulnerability	0-10	$.1x_{212}$	5	.5		
x_{221}	Classified	Violations/Year	1-0	$1-x_{221}$	1	0		

TABLE 11 (continued)

Attribute Number	Name	Units	Range	Utility Function	Present x_i	Present $u(x_i)$	New x_i	New $u(x_i)$
x_{2221}	Personal	Violations/Year	1-0	$1-x_{2221}$	1	0		
x_{2222}	Proprietary	Violations/Year	1-0	$1-x_{2222}$	1	0		
x_{31}	Training	% Of Time	3,9-6	$e^{-(x_{31}-6)^2}$	3	0		
x_{32}	Morale	Rank	0-10	$.1x_{32}$	9	.9		
x_{33}	Motivation	Rating % People	0-20	$.05x_{33}$	20	1		
x_{341}	Timely	Days	60-0	$1-.01667x_{341}$	60	0		
x_{342}	Quality	Rank	0-3	$.333x_{342}$	2	.6666		
x_{343}	Affirm. Act.	%	±9+Nat. Avg-Nat. Avg	$e^{-\left(\frac{x_{343}-}{3}\right)^2}$	70	.06		
x_4	Development	Years Ahead	0-10	$.1x_4$	5	.5		

TABLE 12

MR. THOREEN

$$u(x) = .4u(x_1) + .4u(x_2) + .0667u(x_3) + .1333u(x_4)$$
$$= .4(.5336) + .4(.19) + .0667(.27) + .1333(.5)$$
$$= .3741$$

$$u(x_1) = [(1-.152u(x_{11}))(1-.47u(x_{12}))(1-.094u(x_{13}))(1-.015u(x_{14})$$
$$(1-.658u(x_{15}))(1-.04u(x_{16}))-1]/-.97$$
$$= [(1-.152(.4))(1-.47(.6))(1-.094(.8))(1-.015(.8))$$
$$(1-.658(.2445))(1-.04(.9))-1]/-.97 = .5336$$

$$u(x_{11}) = .538u(x_{111}) + .462u(x_{112})$$
$$= .538(.17) + .462(.6665) = .4$$

$$u(x_{111}) = .5u(x_{1111}) + .5u(x_{1112})$$
$$= .5(.0007) + .5(.3333) = .17$$

$$u(x_{15}) = [(1-.0285u(x_{151}))(1-.04u(x_{152}))-1]/-.057$$
$$= [(1-.0285(.489))(1-.04(0))-1]/-.057 - .2445$$

$$u(x_2) = .273u(x_{21}) + .727u(x_{22})$$
$$= .273(.7) + .727(0) = .19$$

$$u(x_{21}) = .5u(x_{211}) + .5u(x_{212})$$
$$= .5(.9) + .5(.5) = .7$$

$$u(x_{22}) = .7u(x_{221}) + .3u(x_{222})$$
$$= .7(0) + .3(0) = 0$$

$$u(x_{222}) = [(1-.2u(x_{2221}))(1-.163u(x_{2222}))-1]/-.3333$$
$$[(1-.2(0))(1-.163(0))-1]/-.3333 = 0$$

TABLE 12 (continued)

$$u(x_3) = [(1+.456u(x_{31}))(1+.152u(x_{32}))(1+.152u(x_{33}))(1+.304u(x_{34}))-1]/1.52$$

$$= [(1+.456(0))(1+.152(.9))(1+.152(1))(1+.304(.267))-1]/1.52 = .274$$

$$u(x_{34}) = .263u(x_{341}) + .368u(x_{342}) + .368u(x_{343})$$

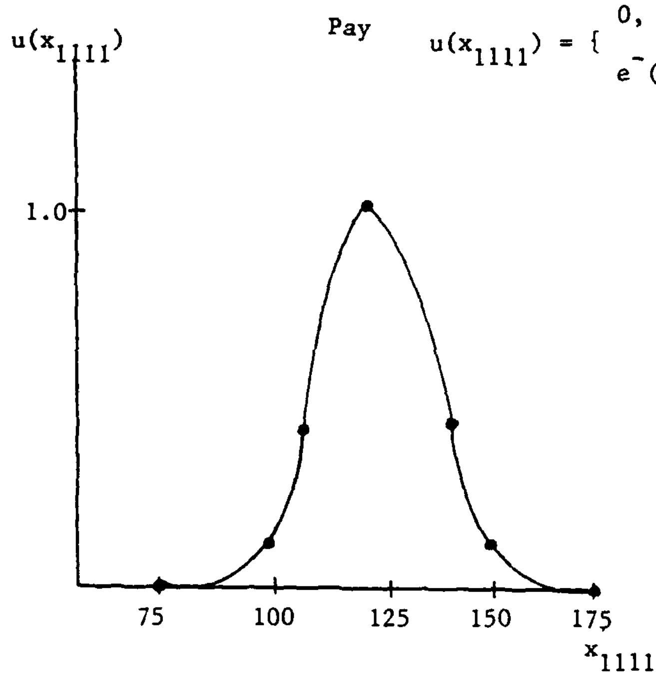
$$= .263(0) + .368(.6666) + .368(.06) = .267$$

MR. THOREEN - ATTRIBUTES

x_{1111}

Pay

$$u(x_{1111}) = \begin{cases} 0, & x_{1111} < 75 \\ e^{-\left(\frac{x_{1111}-125}{16}\right)^2}, & 75 \le x_{1111} \le 175 \end{cases}$$

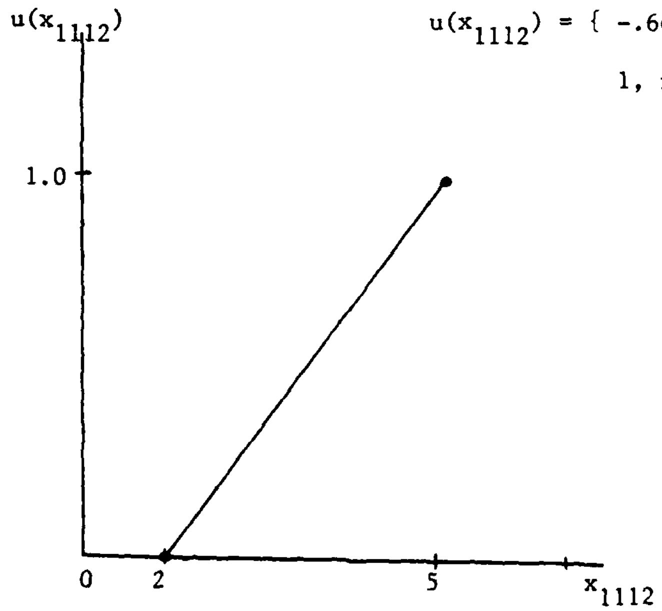


PER CENT PAY

x_{1112}

Customer

$$u(x_{1112}) = \begin{cases} 0, & x_{1112} < 2 \\ -.6667 + .3333x_{1112}, & 2 \le x_{1112} \le 5 \\ 1, & x_{1112} > 5 \end{cases}$$



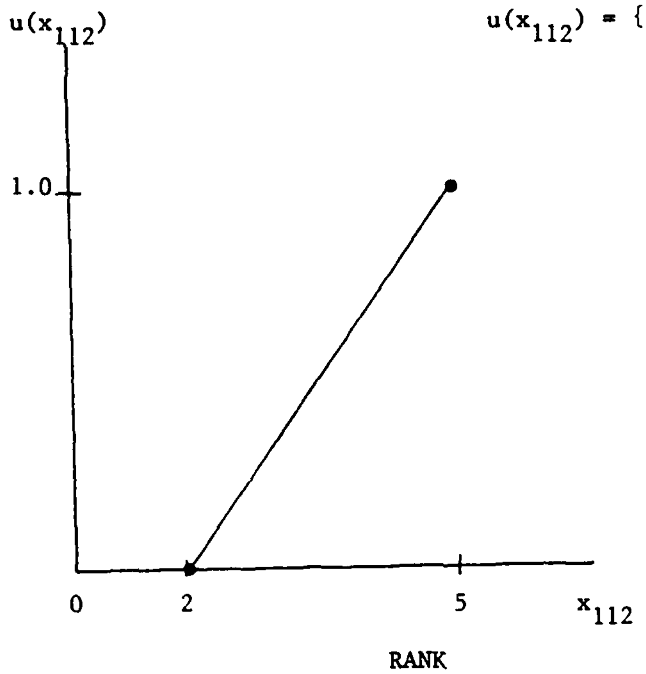
RANK

THOREEN (continued)

x_{112}

Burroughs

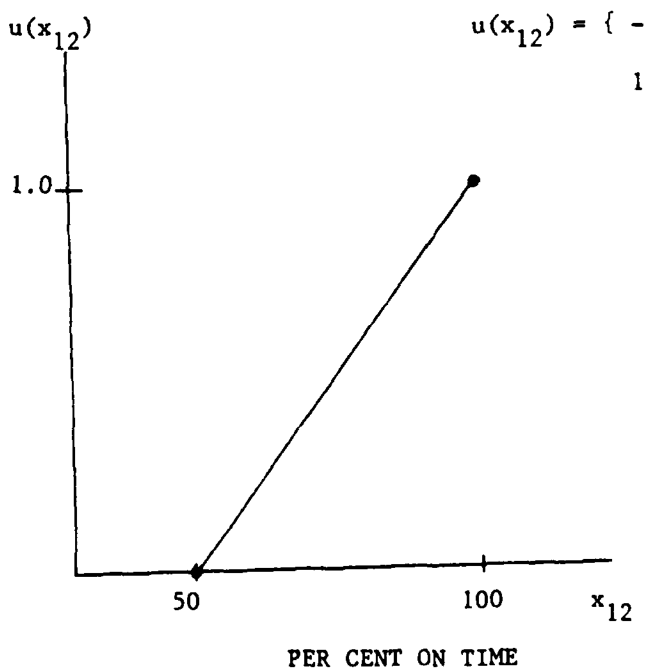
$$u(x_{112}) = \begin{cases} 0, & x_{112}<2 \\ -.6667 + .3333x_{112}, & 2\leq x_{112}\leq 5 \\ 1, & x_{112}>5 \end{cases}$$



x_{12}

Data Reduction

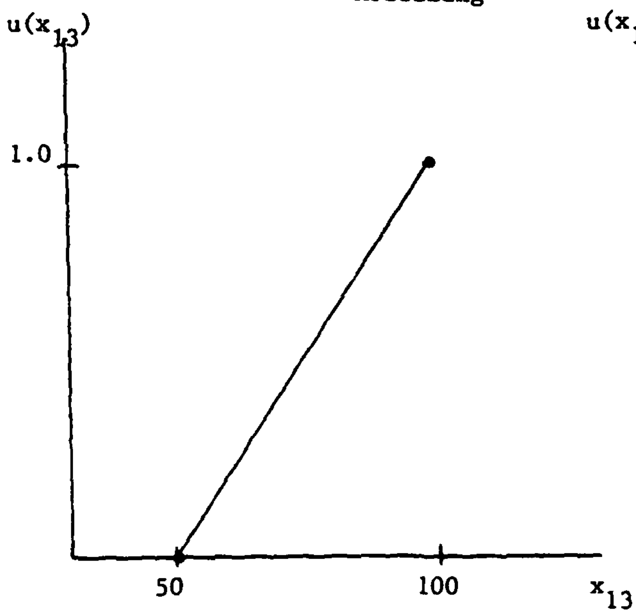
$$u(x_{12}) = \begin{cases} 0, & x_{12}<50 \\ -1 + .02x_{12}, & 50\leq x_{12}\leq 100 \\ 1, & x_{12}>100 \end{cases}$$



THOREEN (continued)

x_{13}

Modelling

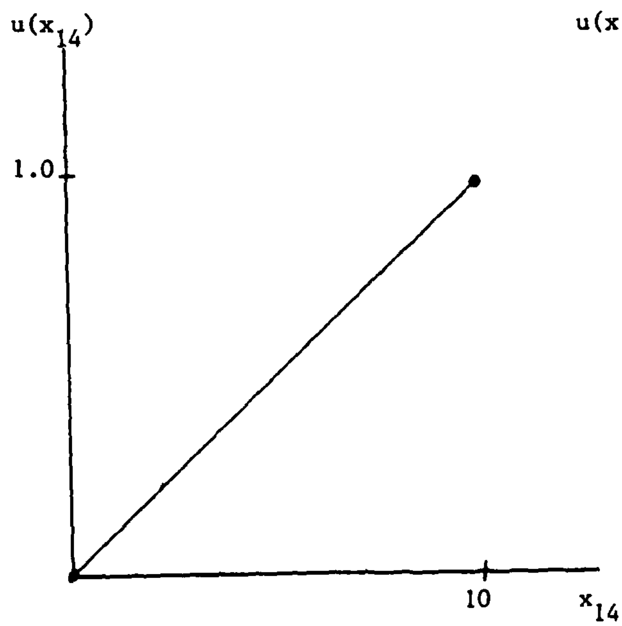


$$u(x_{13}) = \begin{cases} 0, & x_{13}<50 \\ -1 + .02x_{13}, & 50 \leq x_{13} \leq 100 \\ 1, & x_{13}>100 \end{cases}$$

PER CENT MEETING

x_{14}

Hardware



$$u(x_{14}) = \begin{cases} .1x_{14}, & 0 \leq x_{14} \leq 10 \\ 1, & x_{14}>10 \end{cases}$$

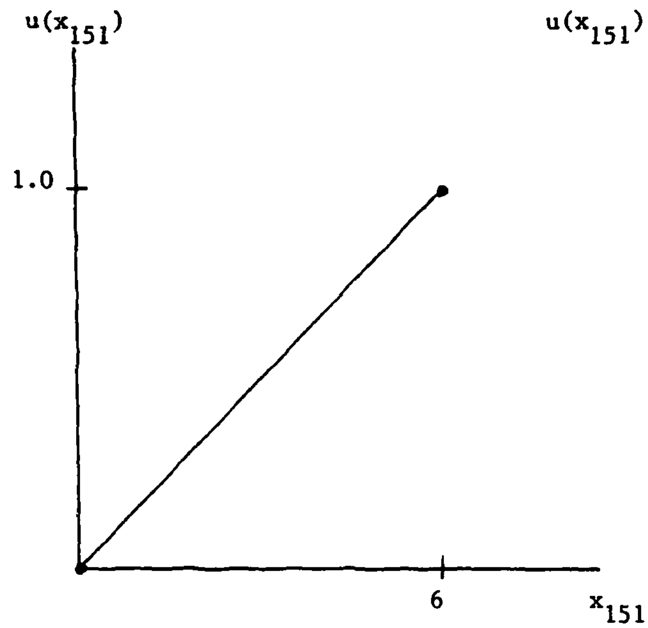
SUFFICIENCY

THOREEN (continued)

x_{151}

Capacity

$$u(x_{151}) = \begin{cases} 0, & x_{151}<0 \\ .163x_{151}, & 0\leq x_{151}\leq 6 \\ 1, & x_{151}>6 \end{cases}$$

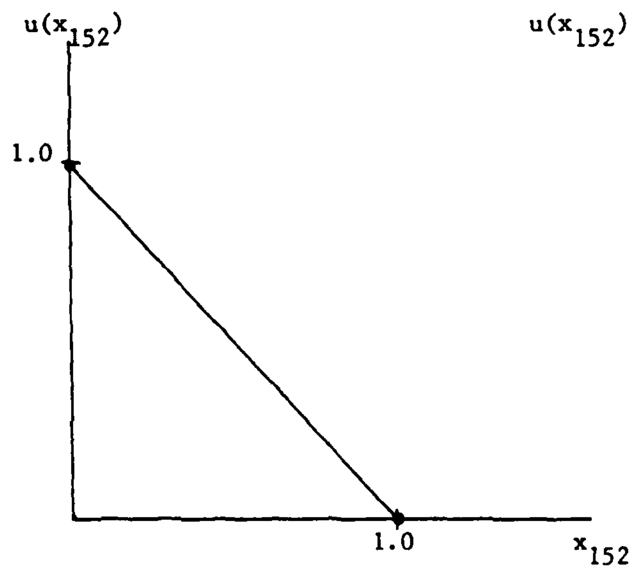


SIMULTANEOUS MISSIONS

x_{152}

Failure

$$u(x_{152}) = \begin{cases} 1-x_{152}, & 1\geq x_{152}\geq 1 \\ 1, & x_{152}>1 \end{cases}$$



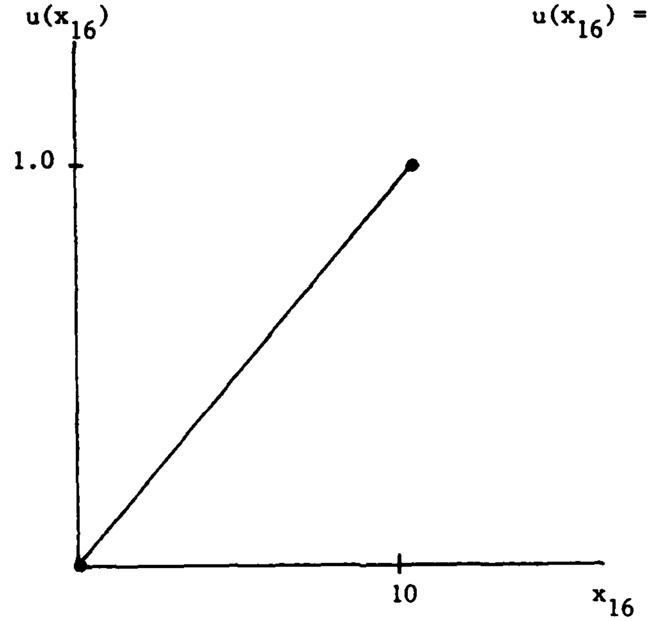
ABORTS/YEAR

THOREEN (continued)

x_{16}

Physical Facilities

$$u(x_{16}) = \begin{cases} .1x_{16}, & 0 \leq x_{16} \leq 10 \\ 1, & x_{16} > 10 \end{cases}$$

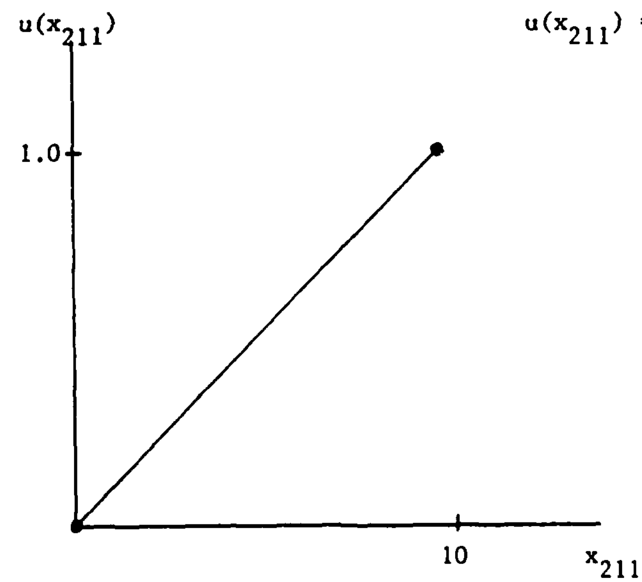


RATING

x_{211}

Accidental

$$u(x_{211}) = \begin{cases} .1x_{211}, & 0 \leq x_{211} \leq 10 \\ 1, & x_{211} > 10 \end{cases}$$



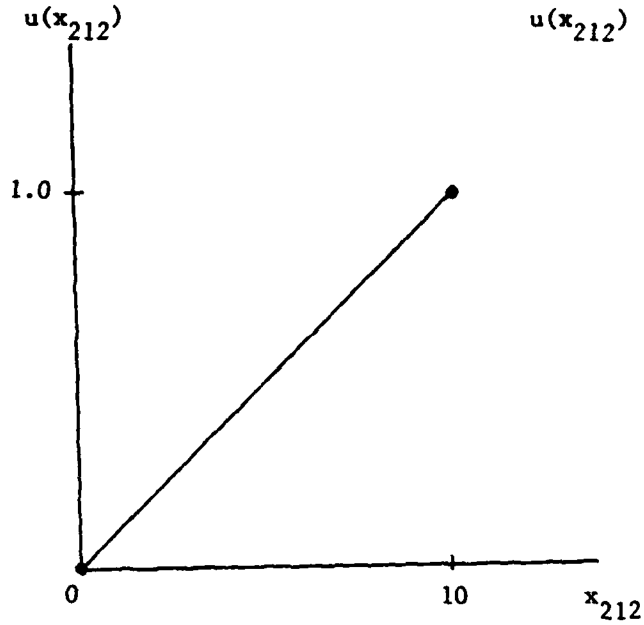
VULNERABILITY

THOREEN (continued)

x_{212}

Deliberate

$$u(x_{212}) = \begin{cases} .1x_{212}, & 0 \le x_{212} \le 10 \\ 1, & x_{212} > 10 \end{cases}$$

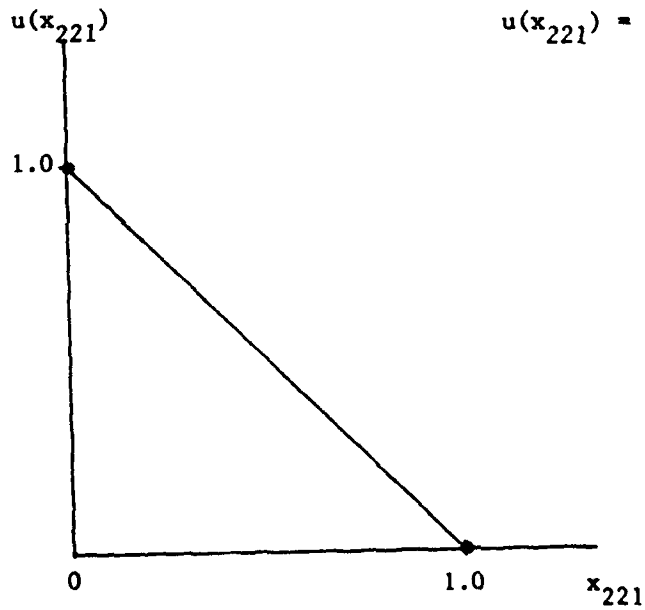


VULNERABILITY

x_{221}

Classified

$$u(x_{221}) = \begin{cases} 1-x_{221}, & 0 \le x_{221} \le 1 \\ 0, & x_{221} > 1 \end{cases}$$



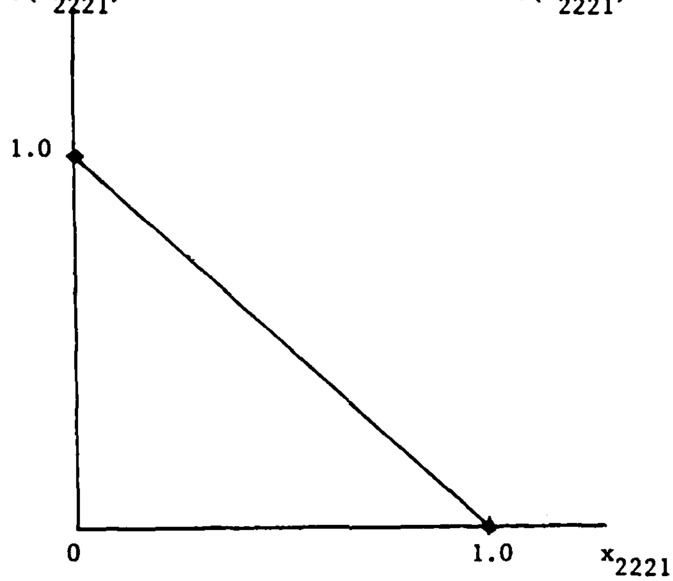
VIOLATIONS/YEAR

THOREEN (continued)

x_{2221}

Personal

$$u(x_{2221}) = \begin{cases} 1-x_{2221}, & 0\le x_{2221}\le 1 \\ 0, & x_{2221}>1 \end{cases}$$

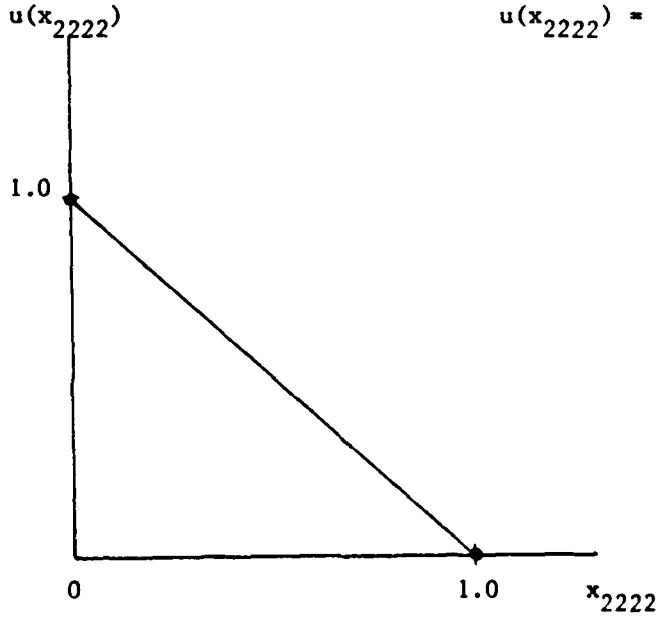


VIOLATIONS/YEAR

x_{2222}

Proprietary

$$u(x_{2222}) = \begin{cases} 1-x_{2222}, & 0\le x_{2222}\le 1 \\ 0, & x_{2222}>1 \end{cases}$$

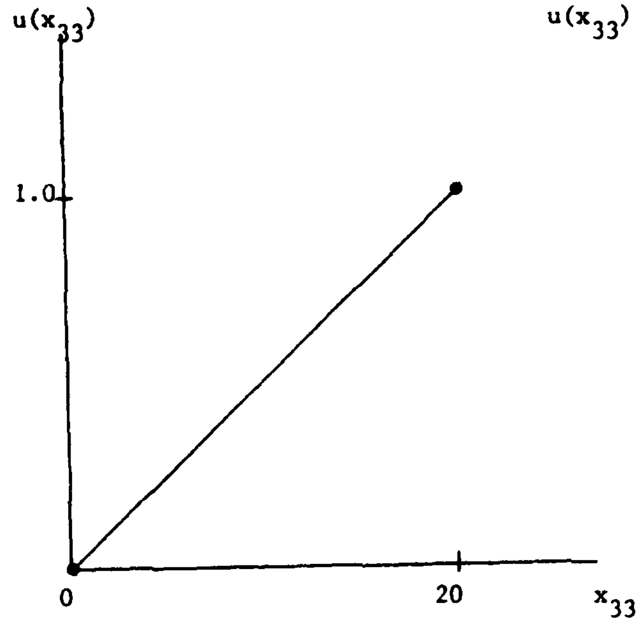


VIOLATIONS/YEAR

x_{33}

Motivation

$$u(x_{33}) = \begin{cases} .05x_{33}, & 0 \le x_{33} \le 20 \\ 1, & x_{33} > 20 \end{cases}$$

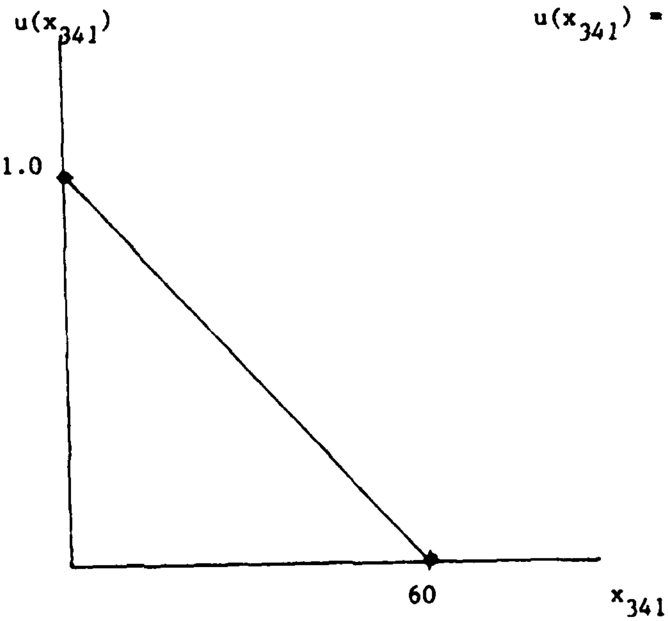


PER CENT OF PEOPLE

x_{341}

Timely

$$u(x_{341}) = \begin{cases} .016667x_{341}, & 0 \le x_{341} \le 60 \\ 1, & x_{341} > 60 \end{cases}$$

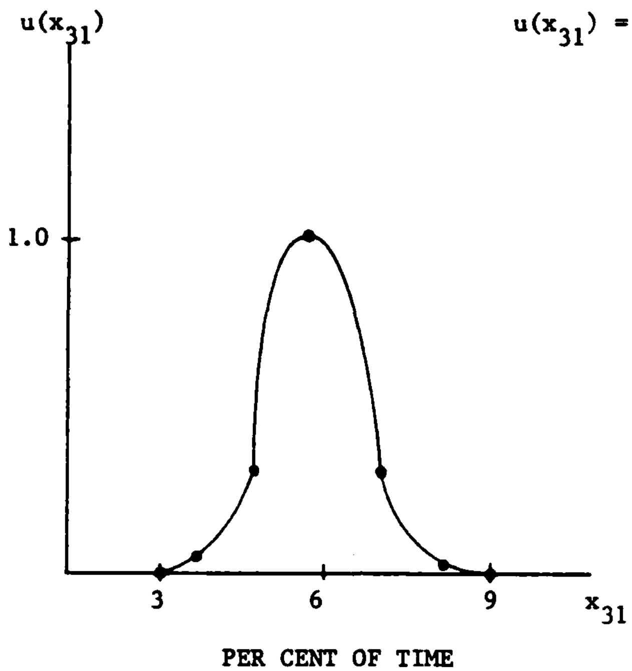


DAYS

x_{31}

Training

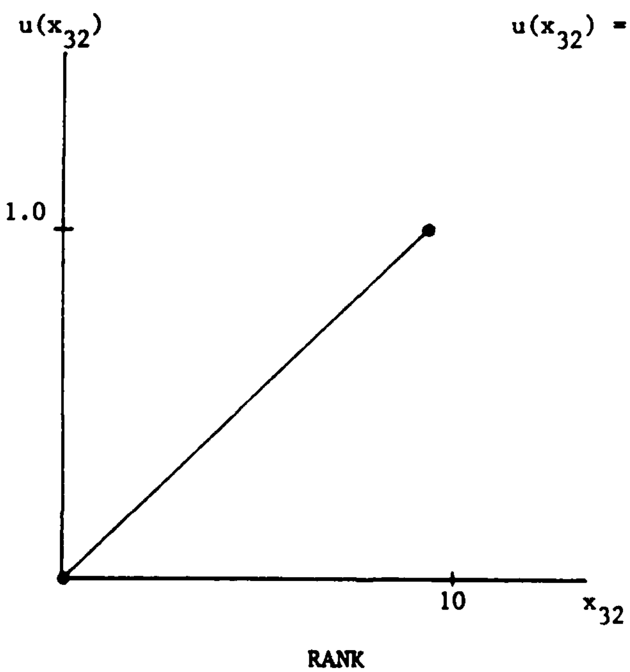
$$u(x_{31}) = \begin{cases} 0, & x_{31}<3 \\ e^{-(x_{31}-6)^2}, & 3\le x_{31}\le 9 \\ 0, & x_{31}>9 \end{cases}$$



x_{32}

Morale

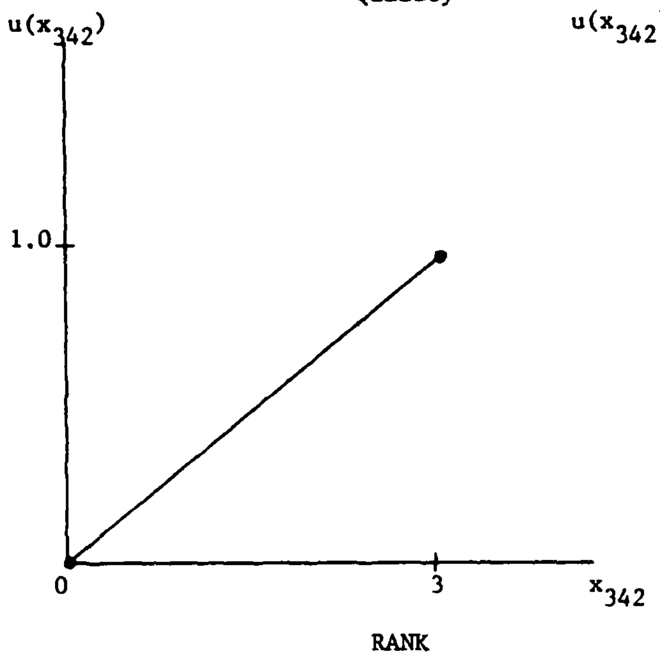
$$u(x_{32}) = \begin{cases} 1x_{32}, & 0\le x_{32}\le 10 \\ 1, & x_{32}>10 \end{cases}$$



x_{342}

Quality

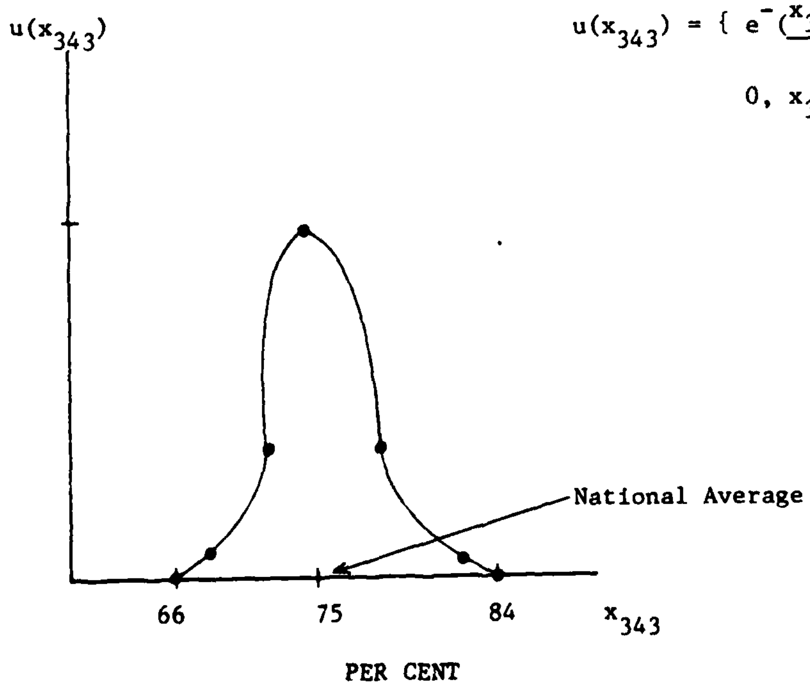
$$u(x_{342}) = \begin{cases} .333x_{342}, & 0 \leq x_{342} \leq 3 \\ 1, & x_{342} > 3 \end{cases}$$



x_{343}

Affirm. Action

$$u(x_{343}) = \begin{cases} 0, & x_{343} < 66 \\ e^{-\left(\frac{x_{343}-75}{3}\right)^2}, & 66 \leq 75 \leq 84 \\ 0, & x_{343} > 84 \end{cases}$$

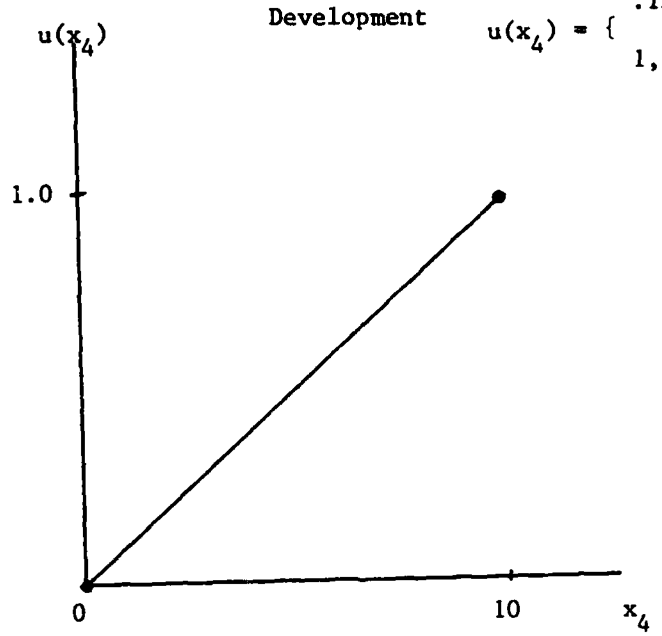


THOREEN (continued)

x_4

Development

$$u(x_4) = \begin{cases} .1x_4, & 0 \le x_4 \le 10 \\ 1, & x_4 > 10 \end{cases}$$



YEARS AHEAD

APPENDIX E

SAMPLE POSITION STATEMENTS

FLEXTIME

MANPOWER EXPERIENCE

MEMO FOR THE RECORD 20 Mar 1980

SUBJECT: Flex Time

TO: AD/SD (Col James Lindsay)

The following is a result of your utility model and is based upon your value judgements regarding the change of flex time back to rigid time. By your model, flex time should be continued in SD.

a. By your value judgements the overall effectiveness of SD would be reduced by over seven percent if SD were to return to rigid time. Most of the loss in effectiveness comes from lowered personnel effectiveness which is estimated at 17 percent.

b. Personnel showed a large loss in morale of 17 percent. This loss is mainly due to employee attitude after the change and would directly effect productivity in the short term due to increased gripe sessions. Training will be lowered about ten percent due to increased scheduling problems. Manning effectiveness will be lowered about ten percent because personnel will not be able to personalize their time under rigid time the way they could under flex time.

c. Other attributes might be adversely effected by a return to rigid time. No attribute would increase in value. The actual decline in effectiveness might be greater than estimated. This decision is not sensitive to changes in the estimates.

d. The Commander of AD may have overriding factors not in the model for SD. The Commander of AD may also evaluate a factor differently at his level even if the factor is in the SD model. For example, morale may decline for SD while morale may improve for AD as a whole if flex time is discontinued in SD. If either of the above is true and strong enough, then the Commander of AD may have a good argument for discontinuing flex time.

e. Critics of utility theory may argue the model is not valid. There is evidence that the model is complete because the wholistic judgement of the SD Commander is in agreement with the model. As more use of the model is made, the case for a complete and correct model will strengthen. In the case of flex time, the form of the model will not effect the decision as no attributes improve in value.

f. If any of the values for attributes within the SD model are disputed, then more information might be appropriate. For example, if one person says time allocation is worse under flex time because people "goof off" more and another says that time is better allocated because each worker can personalize one's schedule, than a work sampling study might swing the final decision either way. In the absence of such criticism, no further study need be done on flex time. The basic decision will remain unchanged.

g. The evidence shown in this model strongly supports the decision to continue flex time in SD.

CHARLES R. WHITE, Lt Col, USAFR

3 Atch
1. Table 1
2. Table 2
3. Table 3

2

MEMO FOR THE RECORD 14 March 1980

SUBJECT: Improved Effectiveness Due Manpower

TO: Col James Lindsay

The following is another result based on your utility model. Your model indicates that the addition of 100 people with your anticipated experience level will improve overall effectiveness by 16.5 percent. If the people have no experience the improvement is 13.5 percent while people with ideal experience level might improve effectiveness by 22.0 percent. The primary area of gain is personnel with improvement of 140 percent. Morale would improve 13 percent. The impact of manning, both direct and in combination with other attributes, forms the basis for this great improvement.

CHARLES R. WHITE, Lt Col, USAFR Cy to: AD/CC (Col Talbot)

APPENDIX F

SAMPLE COMPUTER RUN

TERMINAL PROCEDURES

The following instructions should be followed for using the terminal.

If you do not have a user name and password, you should complete the form on the last page of the manual. Send the completed form to Mr Fred Joines, KRF, 882-4092. Mr Joines will also demonstrate the terminal procedures for you.

The information in brackets is what you must type in. On the same problem I have boxed in the information you would type.

[User Supplied Information]

First you log in and identify yourself.

[LOGIN, "user name," "password," SUP, ADTCVC23]

:

COMMAND - [ATTACH, GO, UTILITY, ID = "user ID"]

:

COMMAND - [GO]

The information from the program will appear as shown on the next page. You will continue on the terminal until you enter EXIT upon request and then either go back to start over or log off.

[EXIT]

COMMAND - [GO] or [LOGOUT]

UTILITY MODEL PROGRAM

FOLLOWING THE PROMPT (>) EITHER:

1) ENTER A REVISED STATUS, OR
2) ENTER A "Y" TO ACCEPT CURRENT STATUS, OR
3) ENTER A "C" TO ACCEPT CURRENT STATUS FOR ALL REMAINING VARIABLES, OR
4) ENTER A "R" TO RETURN TO THE TOP OF THE LIST, OR
5) ENTER "EXIT" TO EXIT THE PROGRAM

VARIABLE	NAME	CURRENT STATUS	RANGE	REVISED STATUS
X11	MANNING	360.0	400 - 0	>365.0
X12	EXPERIENCE	2.0	0 - 3	>y
X13	TRAINING	2.2	0 - 5	>2.5
X141	WORK TIME	44.0	50 - 40	>y
X142	AWARDS	5.0	0 - 5	>y
X143	ADV. OPPORTUNITY	1.5	0 - 5	>c

UTILITY MODEL

ATTRIBUTE NUMBER	ATTRIBUTE NAME	CURRENT STATUS	REVISED STATUS	CURRENT UTILITY	REVISED UTILITY	UTILITY CHANGE
X11	MANNING	360.0	365.0	.100	.087	-.013
X12	EXPERIENCE	2.0	2.0	.444	.444	
X13	TRAINING	2.2	2.5	.440	.500	.060
X141	WORK TIME	44.0	44.0	.600	.600	
X142	AWARDS	5.0	5.0	1.000	1.000	
X143	ADV. OPPORTUNITY	1.5	1.5	.300	.300	
X144	MORALE	8.0	8.0	.800	.800	
X15	ALLOCATE TIME	6.0	6.0	.360	.360	
X21	ORG. BUDGET	75.0	75.0	0.000	0.000	
X22	PROGRAMS BUDGET	90.0	90.0	.184	.184	
X31	QUALITY	6.0	6.0	.600	.600	
X32	SPACE	100.0	100.0	.975	.975	
X411	COST	50.0	50.0	.250	.250	
X412	SCHEDULE	50.0	50.0	.250	.250	
X413	TECH. ACHIEVEMENT	50.0	50.0	.250	.250	
X42	VISIBILITY	50.0	50.0	0.000	0.000	
X51	JOB SATISFACTION	5.0	5.0	.250	.250	
X52	TIME	5.0	5.0	.250	.250	
X0	OVERALL			.272	.274	.002

DO YOU WANT TO REPLACE CURRENT STATUS WITH REVISED STATUS? (Y/N) >>---->y

ENTER "RESTART" OR "EXIT" >>--->restart